INDUSTRIAL ENGINEER

McGraw-Hill Publishing Co., Inc.
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Devoted to the Maintenance and Operation of Electrical and Associated Mechanical Systems in Mills and Factories

G. A. VAN BRUNT, *Managing Editor*

Volume 84 Chicago, April, 1926 *Number 4*

What Is the Age Limit for a Leather Belt?

while one swallow does not make a summer, the data on this belt deserve your attention

I DO not know of any one thing that brings more genuine satisfaction these days than to find that you have obtained your money's worth on a purchase. On the other hand, there is nothing more irritating, especially to an engineer, than to be "stung" by a just-as-good article purchased on the basis that some manufacturers' representatives are better salesmen than liars.

The things I have in mind now revolve around the service furnished by the 42-inch, three-ply leather belt shown in this picture. This belt was installed on a Corliss engine drive in the Brenon Mills at Georgiaville, R. I., in November, 1876, and was in continuous service until the latter part of 1925. It has outlived its maker, the owners of the mill, and the engineers who installed it. During this period of around 49 years, and after 35 years of service, the only repairs were the removing of the inside ply and the addition of a new ply to the outside. This belt has run over a 30-ft. driving pulley and a 7-ft. pulley on the driven shaft. It was originally installed to transmit 500 hp. with the driving pulley operating at 45 r.p.m., but after a few years the speed was increased to 61 r.p.m., giving a belt speed of 5,740 ft. per minute with a driving tension under normal load of 110 lb. per inch of belt width. The belt tension was certainly up around the top limit of accepted practice, if not from 10 to 20 lb. higher than good belt men usually recommend. Besides, the centers measured 31.5 ft. All of these elements, combined with a pulley ratio of more than 4 to 1, did not favor long life for a belt of this size.

A little simple arithmetic shows that the owners of this belt purchased a prize package. The belt cost when new, in 1876, was $1,317.03. The cost of the new ply in 1911 was about $600. Last year when it was discarded it brought $300 making the total cost of this belt $1,617.03.

Some more interesting sidelights on belt depreciation with age have resulted from tests on sections of this belt. The minimum strength of six sections when it was cut up was recorded as 1,870 lb. per sq. in. The maximum strength of the same number of sections was 2,850 lb. per sq. in., making the average around 2,400 lb. per sq. in. On the basis that a new belt of the same quality would have a breaking strength of 5,000 to 6,000 lb., it can be assumed that the old belt depreciated in strength about 50 to 60 per cent during 49 years of service, but even under such depreciated strength, the material was stronger when discarded than the greatest tension that could be applied to it as a belt.

Here are some real facts about a leather belt that should be tucked away and thought about when the question comes up of whether to buy or not to buy a first-grade leather belt. I am not going to ask you to take my word for the accuracy of the figures presented, but refer you to Mr. Louis W. Arny, Secretary of The Leather Belting Exchange at Philadelphia, Pa., who can tell you a whole lot more about this belt drive.

Practical Pete

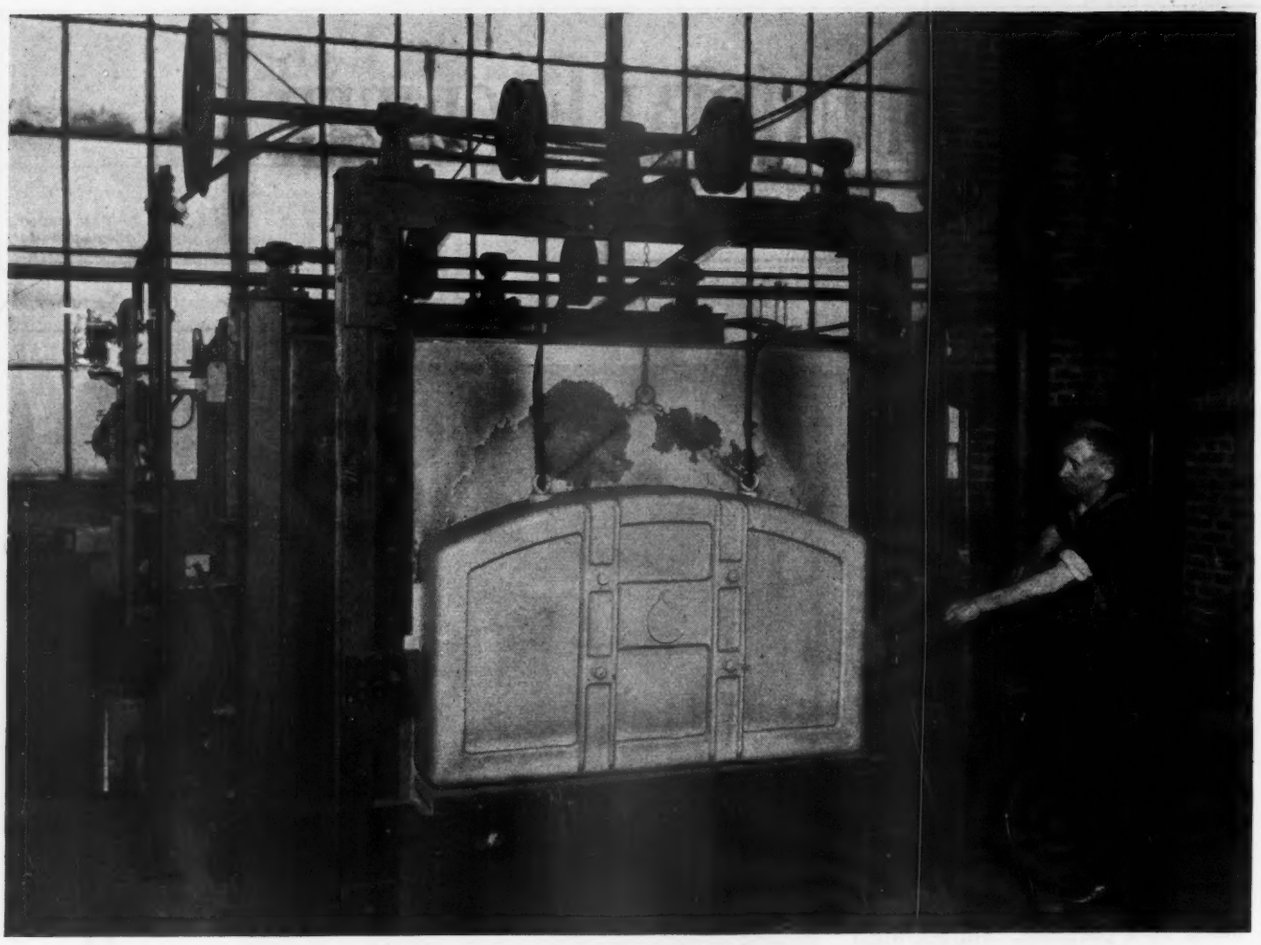

Fig. 1—Standard box-type electric furnace for annealing, hardening, carburizing and other heat treatment processes.

This furnace is rated at 50 kw., 220 volts, three phase and has inside dimensions of 4 ft. wide, 4 ft. deep, and 2 ft. high. It is capable of giving temperatures ranging from 750 deg. to 1,830 deg. F.

Applying Electric Heat in Industrial Plants

together with a discussion of the application of bulk heating, localized heating, and heat treatment processes, including worked out examples that will aid in solving industrial heating problems

By N. R. STANSEL

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THE application of industrial heating can be divided into three fairly well defined classes. In the first class fall those processes in which the form or the character of the raw material is changed and which are also characterized by a low unit value of product, no requirement of exact control of temperature, and bulk of material predominating. Examples of this class are the melting of metals, burning brick, manufacture of cement, evaporation of moisture and similar heating operations.

In the second classification falls the use of heat for local applications, either as individual units, for glue pots as illustrated in Fig. 10, melting pots for alloys, compounds, space heaters and the like and also where the heating unit is built into the machine as in the several types of machinery used in shoe making (one of which is illustrated in Fig. 11), the line casting machine for casting lines of type used by printers, the paper box machine and similar applications. There are a multitude of applications of this kind.

The third class embraces all heating processes in which an even distribution of heat and close control of temperature are essential factors in the success of the use of heat to change the character of a material. The heat treatment of steel, annealing of non-ferrous metals, vitreous enameling, annealing of glass, baking bread, and the like, represent this class as distinguished from the more simple applications of heat to raise the temperature of substances to some approximate value.

In the first class, which can be termed "bulk heating," fuel is, as a rule, the economic source of heat. In some cases it is practicable to use electric heat. This, however, depends upon the nature of the application and the comparative costs of fuel and electric energy. It is in this class that the cost of heat units is the important factor. While on the whole, electric heating, for a long time at least, will be in the minority in bulk heating, there are numerous

applications of electric current in this class on an economic basis. For example, the heating of buildings in the Northwest and in some countries of Europe, the production of steel in the electric furnace, the melting of non-ferrous metals and alloys on a large scale, water heating, and similar applications, all of which indicate the possibilities of electric heat in this first class of heat utilization where conditions make desirable its use.

In general it can be stated that under present day conditions, bulk heating by electric current is not an economic method until the cost of electric energy begins to approach, on a descending scale, one cent per kw.-hr. This, of course, depends on the cost of fuel in any particular locality in which an application of electric heat is desired.

The use of localized heat is particularly the field of the smaller electric heating units. These are made in three principal forms, namely, cartridge units, clamp-on units, and immersion heaters. Here easy divisibility, convenience of application, freedom from effects of vibration, safety, cleanliness, and similar characteristics, of electric heating units, all combine to make electric current an effective and economical method for localized heating.

Fig. 2—Cleanliness is a characteristic of electric heat.

This fact is illustrated by this picture of a battery of seven general japanning ovens at the plant of the Ritter Dental Co., Rochester, N. Y. The connected load of each oven is 42 kw. and is operated from a 220-volt, three-phase, 60-cycle power supply and supplies a range of temperature from 150 to 450 deg. F.

In the third class of heating defined in the foregoing as heat treatment processes, the approximate temperature classification is as fol- temperature classification is as given in the following tabulation:

OVENS	
Drying	Up to 300 deg. F.
Baking varnishes, colors	150 deg. to 300 deg. F.
Baking black varnishes	400 deg. to 500 deg. F.
Baking bread	400 deg. to 500 deg. F.
FURNACES	
Annealing non-ferrous metals	700 deg. to 1,400 deg. F.
Annealing steel	Up to 1,600 deg. F.
Hardening steel	Around 1,500 deg. F.
Carburizing steel	1,500 deg. to 1,700 deg. F.
Annealing glass	Up to 1,200 deg. F.
Vitreous enameling	1,600 deg. to 1,800 deg. F.

While this tabulation gives a general idea of temperatures used for various heat treatment processes, it must be kept in mind that the actual temperature to be used depends upon the material and upon the time during which heat is applied. In other words, for each material and for each process, even in drying, there is some one temperature, or some combination of temperature and time, which will give the best results. With a lower temperature than this value the desired result from heat treatment is not realized. A higher temperature than that necessary in any given case introduces the risk of overheating and in addition is a waste of heat. Thus, while a decision as to the best source of heat for either of the first two classes is, as a rule, not difficult, more thought is required before making a decision in heat treatment problems.

There are, of course, intermediate zones in this classification in which local conditions may influence or fix the choice of the source of heat, and in many cases in these intermediate zones it may be difficult to accurately choose the best method of obtaining the supply of heat energy.

The importance of conducting heat treatment processes at definite and known temperatures has resulted in the development of pyrometry, the science of measuring temperatures above the range of the mercury thermometer. From the first use of the pyrometer as an indicating instrument have come instruments which, through their response to temperature changes within the heating chamber, provide for the control of the flow of heat to the chamber and thus make possible the control of the oven or furnace temperature within narrow limits.

Electric current has been termed the vehicle of heat energy, that is, the current conveys the energy along a definite and predetermined path to the point of application of the heat. Energy is useful only in the degree to which it can be controlled and electric energy has become the giant of industry through the precision and simplicity of its control. This ideal control is the same for the electric oven and furnace as for the other branches of energy utilization. The response of the pyrometer to even very small changes of temperature are exactly translated into the control of the current input to the electric heating chambers so that the flow of heat required to maintain a uniform temperature is a certainty, and this without skill or even thought on the part of the operator. This is an important consideration when the class of help required for the work is not of a high type.

APPLICATION OF RESISTOR TYPE OVENS AND FURNACES

With few exceptions, such as the heat treatment of some of the alloy steels, heat treatment processes are carried on at temperatures below 2,000 deg. F. and are thus within the range of the electric oven and furnace of the metallic resistor type. The resistors, in the form of bars of ribbon, can be distributed around the walls, roof and below the hearth of the heating chamber, thus distributing the flow of heat emitted from the resistor elements. Together with re-radiation from the walls, this makes possible an even distribution of temperature within the heating chamber so that all parts of the charge of material are evenly heated. With the electric oven or furnace, no intervening muffle between the source of heat and the work is

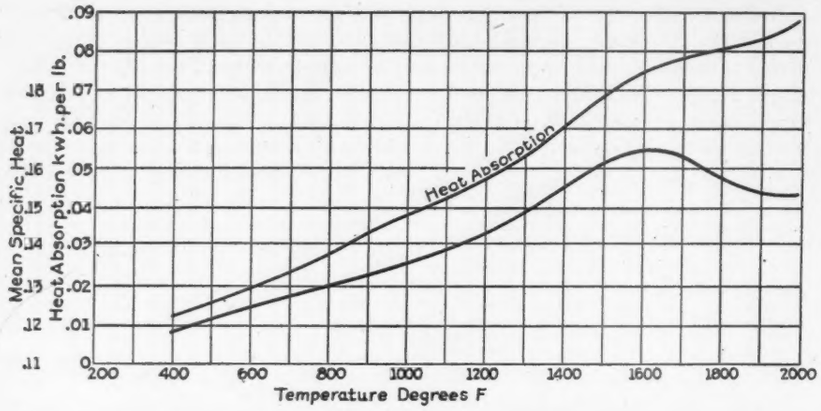


Fig. 3—These curves are used in determining the heat absorbed by a charge of carbon steel.

The lower curve gives the specific heats for temperatures ranging from 400 deg. to 2,000 deg. F. The upper curve gives the heat absorbed in kw.-hr. per lb. of steel for an initial temperature of 70 deg. F. and final temperatures as plotted on the horizontal scale.

needed to protect the material from excessive temperatures and from objectionable gases or to protect the resistors. Herein lies an important factor in the close control of temperature as the use of a muffle introduces a lag between temperature change and response in heat flow.

Control of Atmospheric Conditions in Electric Ovens

The operation of the electric heating apparatus is in itself independent of the atmosphere of the heating chamber, provided that there is no substance, such as sulphur, present in the atmosphere which would attack the alloy of which the resistors are composed. This, together with the fact that the heating chamber of the electric furnace can be made tight, provides for definite control of the oven or furnace atmosphere by the introduction of some inert gas (suited to the material and heat process) into the heating chamber.

The oxidization of the surface of metals in the presence of air is accelerated by heat and scale is formed in proportion to the amount of oxygen (air) available during the heat cycle. The amount of air in the heating chamber of the electric furnace is comparatively small and in many cases is not sufficient to be objectionable as regards scale formation. However, heat treatment is, in the majority of cases, applied well along towards the end of the manufacturing process, and for many tools, and also in the annealing of sheets and wire where the exposed surface is large and thickness small, even a small amount of scale formation is undesirable. The bright annealing of copper wire, through the use of an atmosphere of steam, is an example of atmosphere control. This process is illustrated in Fig. 4 on this page.

On the other hand, there are some heat treatment processes which require oxygen, for example baking varnishes, firing vitreous enamels, and similar applications.

For baking ovens some form of air circulation for the supply of oxygen and removal of vapors and smoke is usually necessary. For japan baking ovens forced ventilation is essential, as about two-thirds of the vapor formed from the naptha solvent is heavier than air and must be removed from the bottom of the oven. In Fig. 2 is shown an installation of japan baking ovens in which forced ventilation is incorporated. Where the size of the oven warrants the application, directed ventilation can be incorporated with some method of heat recovery from the hot gases so as to improve the overall economy of heat utilization.

Fig. 4—This is a water sealed electric furnace for bright annealing of copper wire.

The furnace is rated at 300 kw., 550-volts, three-phase and takes a charge of 6,000 lb. The dimensions of the heating chamber are approximately 6 ft. by 4 ft. by 6 ft. high.

Effect of Electric Heat Load on Power Cost

The method of operation of heating equipment has much to do with economy in the use of heat. Power is purchased—or costs if generated within the industrial plant—on a sliding scale basis, this being accompanied by a maximum demand charge and a power factor charge; in some cases the rate structure is more elaborate than in others. The user of power is interested in the effect that the addition of an electric heating load will have upon the net rate per kw.-hr., as shown in the monthly bill. With the usual form of rate schedule, this depends upon how the heating load is super-imposed upon the light and power load of the plant.

Much of the possible utilization of current for heating is flexible as regards time, hence the placing of the heating load on the user's 24-hr. load chart with reference to the existing maximum demand for power, may be advantageous in that the increase in load does not increase the maximum demand. This, of course, is on the assumption that the demand of the heating load is less than the existing maximum demand, which may or may not be the case.

As the power factor of the resistor type heating load is unity this load adds only to the energy component of the plant load and the result is a betterment of the power factor of the electric load of the plant. Cases where the addition of an electric heating load have eliminated the power factor charge are not uncommon.

While the furnace or oven is at a temperature above that of the surrounding air there is a continuous loss of heat, the higher the temperature the greater the loss. Hence, the heating equipment should be kept in operation only while in use for heating material. Also, when the equipment is heated there is stored in the walls a certain amount of heat, which is a total loss when the heating chamber is cooled to room temperature. To minimize these losses, continuous use to maximum capacity, as nearly as may be possible, is desirable. Depending upon the character and flow of work, one or more small furnaces may be more economical than one large furnace.

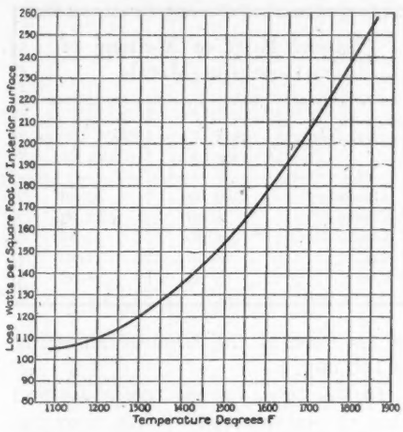


Fig. 5—This graph is used in determining the heat losses through furnace walls.
The curve gives the average losses for a temperature range of 1,100 deg. to 1,850 deg. F. for furnace walls having 4.5 in. of fire brick and 9 in. of heat insulation.

Figs. 6 and 7—At the left is shown an example of bulk heating done by electricity.
Fig. 6 shows an electrically-heated lead melting pot. Calculations of the heating requirements are given on page 158. In Fig. 7 is shown an early type of electric furnace (1919) that is still in use today. This is a box type, direct heat furnace used for hardening tool steel and carbonizing. The temperature range is 1,400 to 1,750 deg. F. The control and pyrometer are shown at the right.

Factors Affecting Power Input to Oven or Furnace

As is typical of electrical apparatus generally, the cost of owning and using electrical heating equipment is comparatively easy to determine. The electrical input to an oven or furnace is the sum of the following items:

(a) Heat absorbed by the charges of material.

(b) Heat absorbed by the walls surrounding the heating chamber.

(c) The heat loss through the walls. (Dissipated at the outer wall surface while the oven or furnace is held at operating temperature.)

(d) For ventilated ovens, the heat absorbed by the air used for ventilation.

(e) The heat required for evaporation of moisture in baking and drying processes.

(f) In melting metals the heat required to supply the latent heat of fusion.

Let us consider each of these items in turn. Item (a) deals with the heat absorbed by the material placed in the heating chamber and is calculated from the following formula:

$P_m = (W \times s \times T^1) \div 3{,}413$ in which

P_m = kw.-hr.

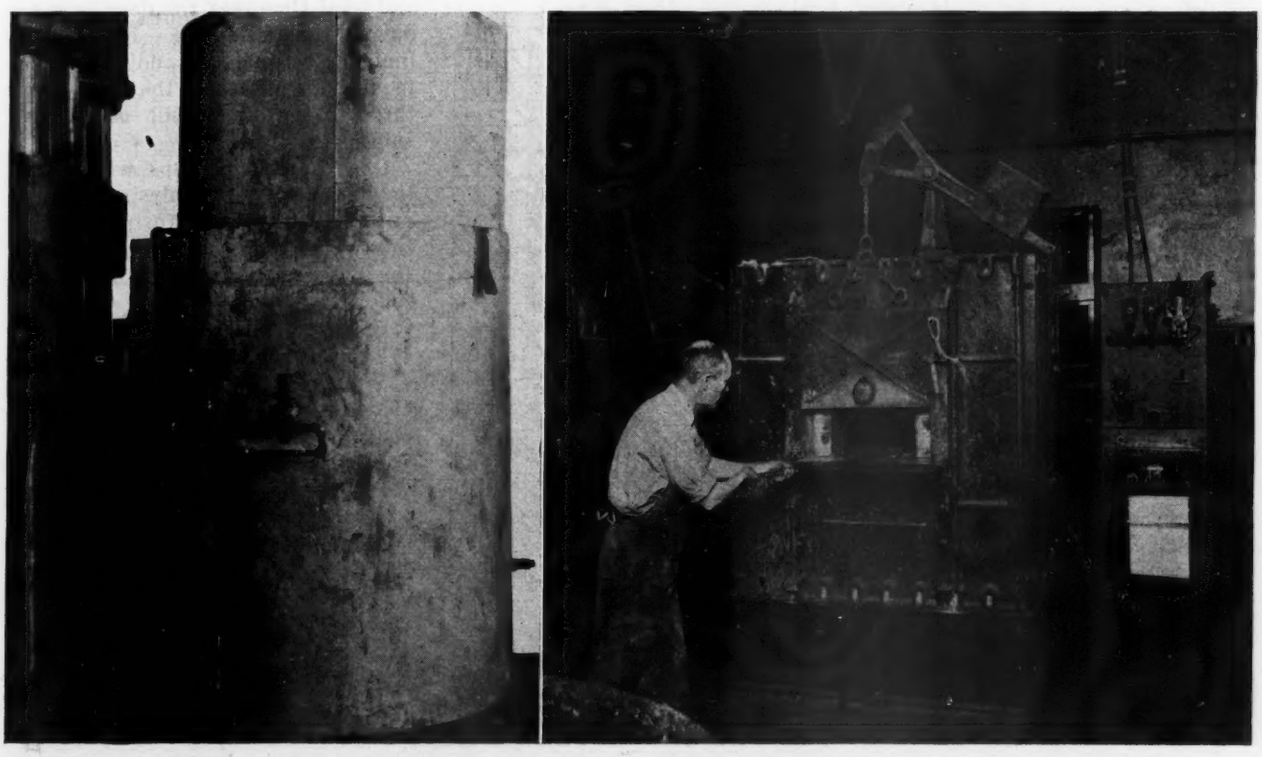
W = weight of the material in pounds.

s = specific heat of the material.

T^1 = temperature rise of the material.

Included in the weight, W, should be the weight of the containers, if any, of the material, which, together with the charge of material, are removed from the furnace at the end of the heat cycle. As the specific heat of materials increases with an increase in temperature, the specific heat corresponding to the average temperature should be used. In Fig. 3 are shown the heat absorption and specific heats of carbon steel for various final temperatures and an initial temperature of 70 deg. F.

Item (b) concerning the heat



stored in the walls is likewise obtained by the equation given in the foregoing. While this amount of heat is lost each time the equipment is cooled to room temperature, if the service is continuous over a considerable period of time the loss by wall absorption becomes a comparatively small item.

The chart shown in Fig. 5 gives average values for item (c) dealing with losses through the furnace walls of a type of construction which is economical for general use with medium and large sizes of electric furnaces. The materials of furnace walls and the thickness may vary both with the service and the size of the furnace. However, the average values given by this chart may be useful for estimating purposes. In Fig. 8 is given the power required to supply the wall losses of electric ovens.

For the ventilation of ovens (item (d) of tabulation on page 157), the heat energy required is given by the curves in Fig. 9 or may be calculated from the following formula:

$P_s = (V \times W \times s \times T') \div 3{,}412$

in which,

P_s=kw.-hr. per charge of material.

V=total volume of air in cubic feet required per charge of material.

W=weight of one cubic foot of air (At 50 deg. F., the weight equals 0.08 lb. approximately).

s=specific heat of air (0.23 approximately).

T'=temperature rise of the air, deg. F.

A box type varnish baking oven usually requires 10 to 20 changes of air per hour. A core baking oven from 4 to 8 changes of air per hour. This in each case must be determined for the class of work that is to be handled.

For the evaporation of moisture (item (e) of the tabulation on page 157), the heat required is:

$P_w = (W \times 1{,}200) \div 3{,}412$

in which,

W=weight of water in pounds.

1,200=number of B.t.u. required to evaporate 1 lb. of water at atmospheric pressure.

As an example of the calculation for determining the heat required for melting metals (item (f) of the tabulation on page 157) let us determine the heat requirements for a lead melting pot such as shown in Fig. 6. This pot is required to melt one ton (2,000 lb.) of lead and to raise the temperature of the liquid lead to 660 deg. F. The temperature of the lead at the time of charging is 100 deg. F.

Latent Heat of Melting of Common Metals

Substance	B. T. U. per Lb.	Watt-Hours per Lb.
Aluminum	180.00	52.80
Copper	78.00	23.00
Lead	9.65	2.82
Tin	25.60	7.50
Zinc	50.63	14.85

In the table on this page we find that the latent heat of fusion or the heat required to convert solid lead at melting temperature to liquid lead is 9.65 B.t.u. per lb. It is also necessary to know the melting point of lead together with the specific heats of solid lead and liquid lead. These data are listed in the following:

Melting point of lead....620 deg. F.
Specific heat of solid lead....0.0306
Specific heat of liquid lead...0.0402
Latent heat of fusion.....9.65 B.t.u

The heat required to convert the lead in accordance with our requirements will be composed of the heat required to raise temperature of lead to melting point, that is, 620 deg., the heat required to melt the lead, and the heat required to raise the temperature of the liquid lead to 660 deg. F.

The heat required to raise 1 lb. of lead to the melting point=(620—100)×0.0306=15.91 B.t.u.

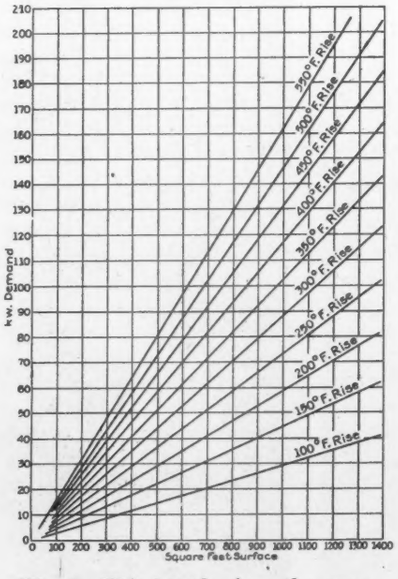


Fig. 8—This graph gives the average energy losses through oven walls.
The losses in kilowatts are plotted against square feet of oven wall surface and curves are drawn for various temperature rises.

The heat required to melt 1 lb of lead=9.65 B.t.u.

The heat required to raise the temperature of 1 lb. of the liquid lead to 660 deg. F.=(660—620)×0.0402=1.61 B.t.u.

The total heat required per pound of lead=15.91+9.65+1.61=27.17 B.t.u.

Heat per ton of lead=27.17×2,000=54,340 B.t.u.

Kw.-hr. per ton=54,340÷3,412=15.9 kw.-hr.

The actual kw.-hrs. per ton would depend upon the degree of heat insulation of the heating chamber and upon the method of operation. The electrically heated lead pot shown in Fig. 6 has a melting capacity of 3,500 lb. per hour. Under average conditions of one shift per day and including operation of the pot so as to hold the lead at working temperature overnight, the energy consumption is approximately 30 kw.-hr. per ton. For two shifts per day, approximately 25 kw.-hr. per ton is required. This is a use of electric current for bulk heating where the effectiveness and convenience of electric heat justifies its use.

Example of Heat Unit Costs of Electric Furnace

The open door loss of ovens or furnaces must be estimated from the size of the door opening, temperature of the heating chamber, and total time that the door is open during the heat cycle. For a preliminary estimate an addition of 25 to 50 per cent of the heat loss through the walls will usually be sufficient.

One example perhaps will suffice to illustrate the analysis of heat unit costs of electric furnaces. For this we assume a box type furnace for annealing steel, for which the following data are given:

Capacity, 800 lb. per hour.

Temperature, 1,500 deg. F.

Time of heat cycle, 45 min.—includes time for charging and discharging.

Furnace charge, 600 lb.

Size of heating chamber, length 82 in., width 45 in., height 33 in.

Assuming an initial temperature of about 70 deg. F., the heat absorbed by the steel per hour, from the equation given in third column of page 157 or from curve given in Fig. 3, is:

$P_m = [800 \times 0.16 \times (1{,}500 - 70)] \div 3{,}412 = 54$ kw.-hr.

The inside area of the heating chamber is 109 sq. ft. From Fig. 5, the constant loss through the walls while the temperature of the heating chamber is maintained at 1,500 deg. F. is found per sq. ft. of interior surface and multiplying this by 109 sq. ft. we obtain approximately 16 kw. The total power consumption is then 16+54=70 kw.-hr. per hr.

The maximum demand will depend upon the actual kw. in resistor capacity installed in the furnace. To shorten the time required for heating up from room temperature it is customary to make some addition, from 10 to 15 per cent, to the capacity required for the normal heating service. In this case, say 80 kw. would be the maximum demand.

To arrive at the total energy used over a period of time, it is necessary to base the estimate upon some definite method of operation and to take into account the loss of heat due to cooling during the hours the furnace is not in operation.

For the furnace which we have assumed, operating 48 hr. per week of 5½ days, the total weight of steel heated per week would be 38,400 lb. The corresponding total amount of heat absorbed by the steel is 2,575 kw.-hr. The average loss due to cooling must be estimated. In this case an average loss by cooling overnight of 10 kw.-hr. per hour, and over the week end 5.5 kw.-hr. per hour, would be reasonable values.

The heat loss for the week will be:

16 kw.×48 hr.=768
10 kw.×77 hr.=770
5.5 kw.×43 hr.=237

Total.....1,775 kw.-hr.

The total power consumption per week is then equal to 2,575+1,775=4,350 kw.-hr.

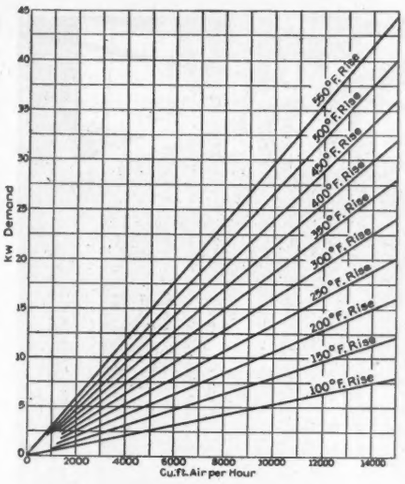


Fig. 9—Energy required for heating the ventilating air of ovens.
The volume of air to be heated is plotted against energy required to heat the air. Curves for various temperature rises are given.

While for a given temperature rise, the heat absorbed by the charge of material is constant, regardless of the time of heating, the total heat required by the furnace depends upon the length of time of heating. This is of course obvious from the fact that the loss through the walls while the heating chamber is held at working temperature is constant. Hence, the shorter the heating period (which varies over a wide range for different classes of work), the less the power consumption per pound of material.

Cost of Heat Compared to Cost of Finished Product

Perhaps there is nothing so well known among oven and furnace users today as that the cost of heat units required for heat treatment processes—whatever may be the source of heat—is but a small percentage of the total cost of the finished article. Hence, an analysis of the cost of owning and operating heating equipment should go beyond a comparison of heat unit costs and bring into the reckoning the many other items on which depend the cost of production.

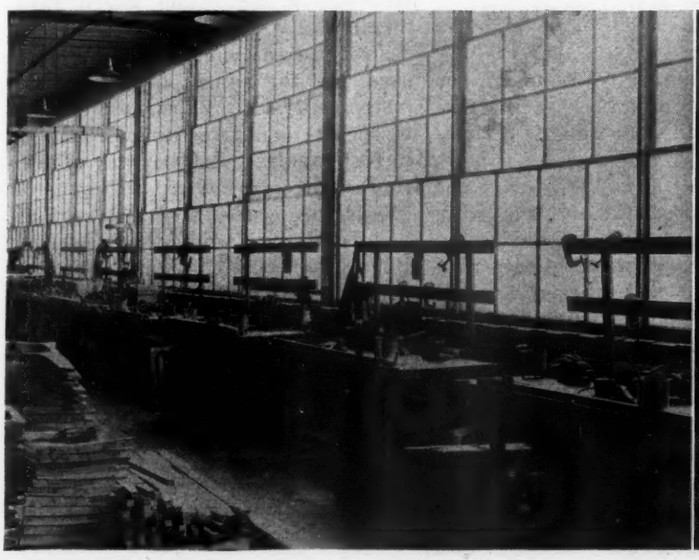
Included in the list of charges which go to make up the cost of the finished manufactured article are:

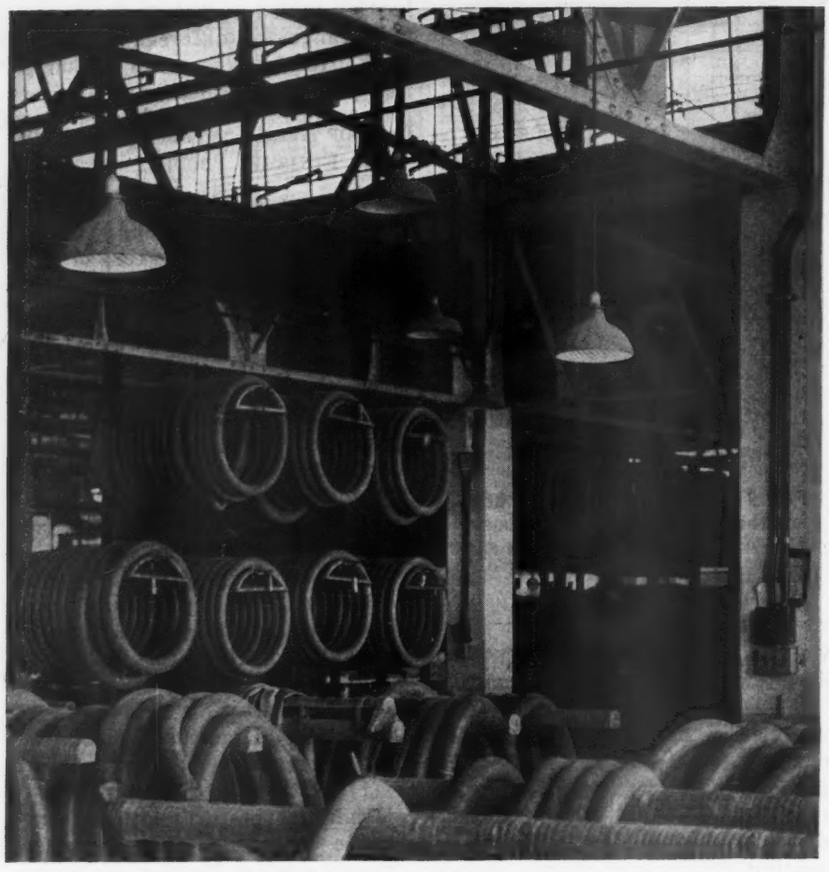
(a) The overhead cost.
(b) Maintenance.
(c) Labor cost.
(d) Cost of raw material.
(e) Cost of rejected parts.
(f) Rate of production.

High temperatures are the most prolific source of maintenance charges against heating equipment. It would be surmised that the maintenance cost of electric heating is low, because it is not necessary to create an excess of temperature in any part in order to obtain a desired temperature in the heating chamber, that is, the resistors operate at a temperature not far above that required for the heat process. At temperatures below 2,000 deg. F. the alloys used for the resistors have a long life. In furnaces the fire-brick

(Please turn to page 176)

Figs. 10 and 11—Two good examples of localized heating.
In Fig. 10 is shown an installation of two small cartridge units which are in a leather embossing machine at the Worcester (Mass.) plant of the Graton & Knight Mfg. Co. In Fig. 11 is shown an installation of 350, 1-qt., aluminum jacketless glue pots, in the woodworking department of the Willys-Overland Co., Toledo, Ohio.





Final inspection of inner tubes requires an intensity of 25 to 35 ft.-candles. This high level of illumination is obtained by suspending over each inspection rack, one No. 815 X-ray reflector and 200-watt lamp.

Considerations involved in

Planning Lighting System for a Tire Factory

with method of determining size and number of lamps necessary for illumination required, and factors that influenced layout of distribution system

By PHILIP CHAPIN JONES
Electrical Engineer, The Goodyear Tire and Rubber Company, Inc., Akron, Ohio

GENERAL principles underlying illuminating engineering apply, of course, to all installations. Nevertheless, their practical application to specific cases requires the exercise of good judgment in order to obtain the desired results. Some time ago the task of designing the lighting system for a large automobile tire factory devolved on me, and in this work some interesting problems were solved.

The system ultimately chosen resulted from a close study of the general arrangement of the factory, the illumination intensity required for the processes used, the spacing distances and mounting heights permissible, and so on.

In this instance, the processes which influenced the lighting were as follows: (1) Washing, wherein the crude rubber is fed between rolls to be washed and worked for the purpose of removing dirt and impurities. The nature of this work does not require a high intensity of illumination. (2) Milling, in which process the ingredients necessary to give the desired characteristics are worked into it. This operation requires higher intensity of illumination than does washing. Furthermore, the problem of obtaining proper lighting for this process is complicated by hoods over the machines. (3) Calendering, in which the rubber is rolled into sheets and gaged for thickness. Fairly high intensities are required for this work in order to detect imperfections. The work is in a vertical plane. (4) Tire building and finishing operations also require a rather high intensity of illumination. Moreover, it is necessary that the light come from low angles as the work must be closely inspected at all stages of the processes. The nature of the equipment and the conditions surrounding these processes are shown in the illustrations. The other processes involved in the manufacture of tires are not so exacting in their illumination requirements.

In all of these processes the work to be illuminated is black or very dark in color. For this reason higher intensities than usual are required, especially where the work must be inspected. For the dark fabrics dealt with in a tire factory the coefficient of reflection is 0.1, or less.

The lighting intensities required were determined by experiment, as we felt that this was the best way of solving the problem. Lamps of different sizes were tried in turn above the machines and the operators were asked to tell when, in their opinion, the illumination was sufficient for speedy, safe, and accurate work. Then the intensity of the light at the working plane was measured by means of a photometer which gave the illumination in foot-candles. If desired a foot-candle meter could be used for the same purpose. This instrument is not expensive, is easy to operate and gives direct readings in foot-candles. Another way of getting such information for general use is to secure it from various handbooks or from the Lighting Bureau of the National Electric Light Association, Nela Park, Cleveland, Ohio. This bureau has tabulated the intensities recognized as good practice in practically all of the leading industries. After the desired lighting intensity has been determined in any manner, good judgment must, of course, be used in changing the values as needed.

In this tire factory it was found,

as explained above, that if a general lighting scheme were used an average of 5.5 ft.-candles would be sufficient. Higher values might bring greater over-all economies and, in fact, in certain parts of the plant greater values are now in use. Again, the intensity of lighting necessary in certain places is considerably higher than it is in others. Thus, from 1 to 2 ft.-candles was found sufficient for storage, while from 20 to 40 ft.-candles are needed for inspection work. As it would be extravagant to maintain an average of 20 to 40 ft.-candles over the whole plant, local lighting was superimposed upon the general lighting in the few special places where these higher intensities were needed.

Assuming that the illumination required is 5.5 ft.-candles, the amount of light flowing to each square foot of working plane must equal 5.5 lumens. It would not be correct, however, to choose the size of lamps on this basis because some of their light is wasted in the reflectors and some is wasted by striking columns, machinery and other obstructions. With the R. L. M. standard dome reflector, which was chosen as the best for this installation, only 70 per cent of the light is usable, as 30 per cent is wasted in the reflecting surfaces, and otherwise. Therefore for this reason the amount of light flowing per square foot must be $5.5 \div 0.70 = 7.86$ lumens.

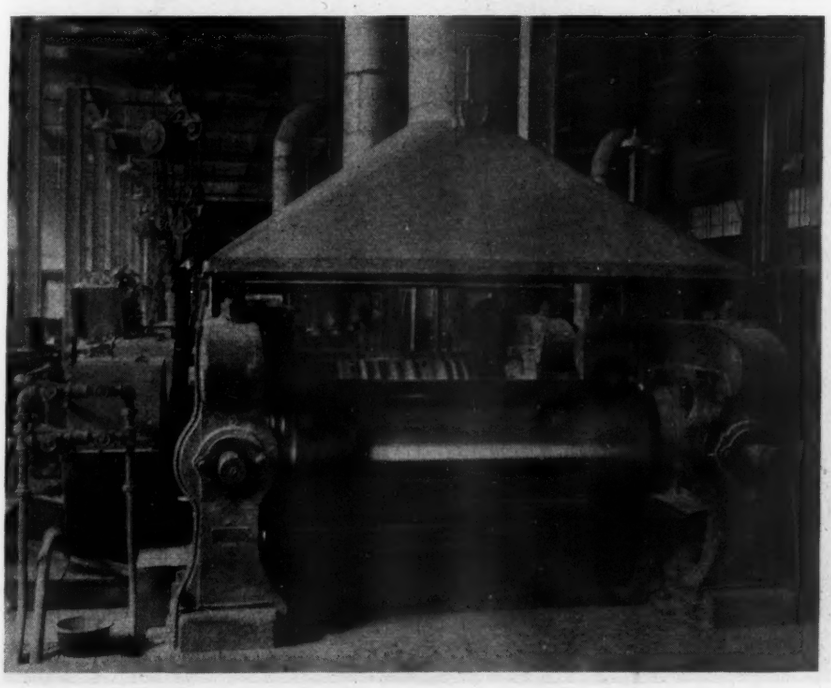
This does not take into account the light lost by striking machinery, columns and the like, which was figured in this case as amounting to 15 per cent, leaving available 85 per cent of the light. This 85 per cent is called the "Utilization Factor." This factor varies according to the color of the equipment and walls in the plant and the amount of obstruction in the form of pillars, belts and so on. With this utilization factor of 85 per cent, the total light sent out by the lamps must be further increased to $7.86 \div 0.85 = 9.24$ lumens per square foot. Having obtained this figure it was easy to calculate the watts per square foot as the average output value of type C gas-filled lamps is about 13 lumens per watt. Then the watts required equals $9.24 \div 13 = 0.711$ watts per square foot. Using this figure the size of lamps necessary was calculated as described later.

A system of general lighting rather than local lighting was adopted because the former was cheaper in this case and would light the plant quite as well if a few units for local lighting were also used. The cost of a lighting system consists of operating expenses and fixed charges; and fixed charges are proportional to the cost of installation. A brief study shows that the most costly items of a lighting system are the reflectors, lamps and switches. By reducing these to a minimum the lowest over-all cost may be obtained. Exclusive of the main supply lines, the cost of the general system decided upon was divided about as follows: Fixtures (including lamps), 61.8 per cent; switch wiring, 25.1 per cent; and main wiring 13.1 per cent.

As a good rule to follow it may be stated that where a few operations or machines are used over a large area, local lighting is cheaper as there is but one reflector, lamp and switch for each machine, and very few of these per 1,000 sq. ft. Where a large number of machines or operations are crowded into comparatively small areas, general lighting is cheaper, as fewer reflectors, lamps, and switches are required.

The operating costs are determined by the number of reflectors, lamps and switches installed. Reflectors must be cleaned, lamps renewed, and switches repaired. There is, however, one other factor that often assumes large proportions; namely, changes in location of equipment. If equipment is being moved about frequently the cost of moving the local lighting units becomes a large part of the operating cost. With general lighting, where the lamp locations are independent of the machinery locations, this factor does not enter. The tire industry is comparatively new and its processes are constantly being changed or improved. Expansion is also rapid and the demand changes from one set of sizes to another, or from one type of tire to another. All of these changes demand new layouts and the expense of changing local lighting systems would probably exceed all other items of operating cost. As the lighting distribution factor of a tire plant is high, the choice of general lighting becomes obvious.

With a building construction having definite bays separated from each other by columns and deep beams, it is necessary to take the bay as a unit of area in designing the lighting system. The lamps must be more or less symmetrically placed in each bay and all bays must be alike. As the bays in this factory are 20 ft. by 20 ft. they require a total of 284 watts each, on the basis of 0.711 watts per sq. ft., which was the figure found necessary to give



Milling the rubber requires a fairly high intensity of illumination.

In this operation, coloring matter and other ingredients are thoroughly mixed into the rubber by passing it through these rolls. Light is thrown directly on the rolls by a 50-watt lamp suspended from a drop cord which passes through the hood. A socket and plug are used just above the hood to allow removal of the latter for repairs. Armored conductor is used in passing through the hood. Type PWP cord is employed between the ceiling and the socket, to take up vibration.

5.5 ft.-candles. Using standard size lamps would round this off into 300 watts per bay, giving slightly more than 5.5 ft.-candles average intensity. This wattage might be supplied in either two 150-watt lamps, three 100-watt lamps, four 75-watt lamps, or six 50-watt lamps. The determining factor is the distribution, as the fewer lamps used the less would be the cost of the system.

The relation between minimum and maximum intensity in a bay should be as near unity as is possible with reasonable economy. To determine this point the test shown in the accompanying table was made of the relation between the number of lamps and the ratio of the various intensities resulting. This test was made under the conditions that there were no obstructions to cast shadows, the bays were 20 ft. by 20 ft., the mounting height was 9 ft. above the working plane, and the reflectors were R. L. M. standard dome. Four bays, a section 80 ft. by 80 ft. square, were lighted while the test was made so that light from the four bays came to every point.

It was apparent from this test that it would be unnecessary to use more than three lamps per bay, as a ratio of 0.950 was obtained with three lamps. If the conditions assumed in computing these figures—no shadows and large spaces—could always be realized, two lamps per bay would be adequate, as with these the ratio would be 0.788. However, in practice this is not possible; so three units per bay were chosen. Moreover, the choice of three units per bay was desirable in this case for another reason. With the units selected, each has a 100-watt lamp. If it is so desired in the future the intensity may be increased 50 per cent without changing the reflectors, as a 150-watt lamp will fit the same equipment. In parts of the plant this has already been done.

In order to have the fixtures above the bottom of the I-beams, thus affording protection, and at the same time giving a more even distribution of light, a mounting height of 11 ft. 6 in. above the floor was selected.

For construction reasons and because any partitions erected will ordinarily follow bay boundaries, the control of the lamps should ordinarily be divided according to bays with one, two or three bays per switch. If all the lamps were lighted at once the cheapest arrangement, from the standpoint of installation, would be to control three bays by each switch. Much of the time, however, only small sections of the lighting system are in use. By the use of fewer switches a saving would be made in first cost, but this would be at the expense of an increase in operating cost, caused by lamps being burned unnecessarily. This problem is not subject to precise solution and, as the best compromise, the practice of controlling two bays per switch was chosen. A typical section of the factory is shown in one of the illustrations. The lamps are arranged three in each bay, symmetrically with respect to the bay and in orderly rows across the entire plant.

After these details had been settled the distribution system had to be designed, keeping these factors in mind: An adequate supply of power for lighting under unexpected conditions must be assured; changes must be easy of accomplishment; the construction must be rugged, and at the same time economical. Efficiency in the use of materials and labor must be the keynote.

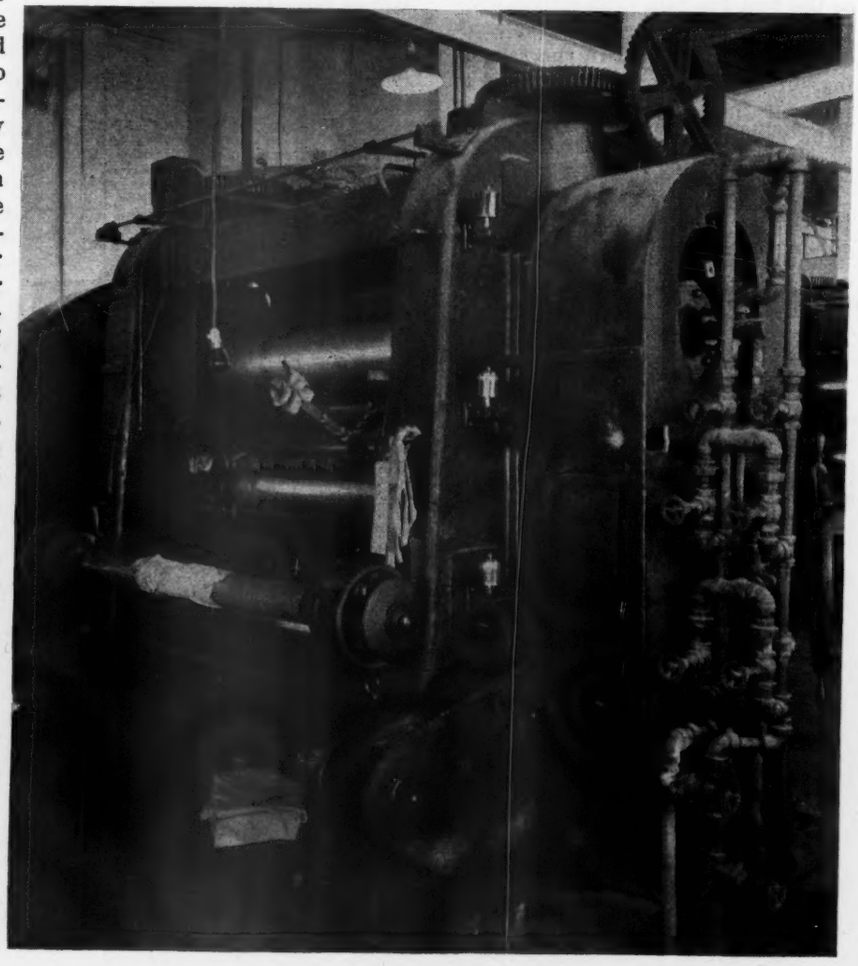
The average connected load is 0.75 watts per sq. ft. (three 100-watt lamps in a 20-ft. square bay) or a total of about 365 kw. for the building, including basement. However, as lighting intensities are increasing it seemed wise to allow a capacity of at least 1 watt per sq. ft., as a basis of feeder capacity, thus giving a total connected load of approximately 550 kw.

The primary voltage is fixed generally by considerations other than lighting distribution. In this case, energy is obtained from the power house about 1,000 ft. distant. Obviously, it would not be wise to transmit at the lamp voltage currents of several thousand amperes. However, 2,300-volt, three-phase energy was available and as this was being used for all power distribution it was the natural choice for the lighting distribution as well.

For the lamp voltage there can scarcely be said to be any choice at

Calendering also requires a high level of illumination.

The rubber is rolled into sheets of definite thickness on these rolls and must at the same time be inspected for imperfections. As the general illumination of approximately 5.5 ft.-candles is not sufficient for this work, it is supplemented by the use of a 50-watt lamp in a half-reflector guard, which throws light onto the rolls.



all. While 220 volts are still used to some extent the lamps at that voltage are more expensive, less efficient, and more fragile. In the vibration existing in most plants their life is very short. They are also at a disadvantage from a safety standpoint, particularly where extensions are used. Thus 110 and 120 volts are being used more and more, and a great many 115-volt lamps are in use. This is a very good value, linking in with the 230-volt and 2,300-volt series which are now more common than the older 110, 220 and 2,200 volts. We decided to use 115 volts.

Although the choice of 115 volts for the secondary system is simple, the choice of the type of secondary distribution is not so obvious. There are three possibilities which, with their corresponding percentage currents for any given load, are shown below:

Volts	Type	Per Cent Current
115	1 phase	100
115	3 phase	57.7
230/115	3 wire	50.0

In deciding between these three possibilities there are several factors to be considered. The basis of comparison is the relative economy of operation of the three systems when designed for equal line drops. Under this condition the controlling factors are total copper required and line losses (I^2r).

Omitting the very simple calculations required, we obtain these results.

System	Number of Wires	Copper Required Per Cent	Losses Per Cent
115 volts, 1 ph.....	2	100.0	100.0
115 volts, 3 ph.....	3	75.0	100.0
230/115 volts, all conductors same size	3	75.0	50.0
230/115 volts neutral one-half size	3	62.5	50.0

Omitting Case 3, which for an ordinary lighting system would be indefensible, the three-wire system seems at first sight to offer some economies, although the figures given are for cost of copper only. The complete cost of installation, including cost of all material and labor, would not stand in a similar ratio.

The three-wire system has, however, certain objectionable features which may offset its advantages. First, bringing 230 volts, instead of 115 volts, into the lighting cabinet entails increased danger to employees, with greater liability of short-circuits, and likelihood of greater damage by them when they occur. With the three-wire system there is also the possibility of bringing 230 volts directly into the sockets by careless wiring, which unfortunately we always have to consider.

Aside from these disadvantages, which are potential rather than actual, there are one or two relating to transformer grouping. With a three-wire system each bank takes energy from a single phase only, so that where the supply is three phase there is usually an unbalanced circuit. The primary wiring arrangement is also not so convenient, for cable is generally used and it is necessary to make an awkward, single-phase termination for a three-phase cable or to use both three-conductor and two-conductor cable which, of course, increases the stock of spare cable to be carried. Furthermore, where a bank consists of one or at the most two transformers, any transformer trouble will cause a loss of lighting until the defective transformer is replaced. With a three-phase system using three transformers per bank in closed delta, if there is trouble on one transformer it can be cut out and a good portion of the load carried on the other two in open delta until the third transformer is replaced.

Where smaller total capacity is desired, open-delta banks or single-phase banks may be used with a slight decrease in reliability. In the plant under discussion the decision was made in favor of the three-phase system. It was felt that the many

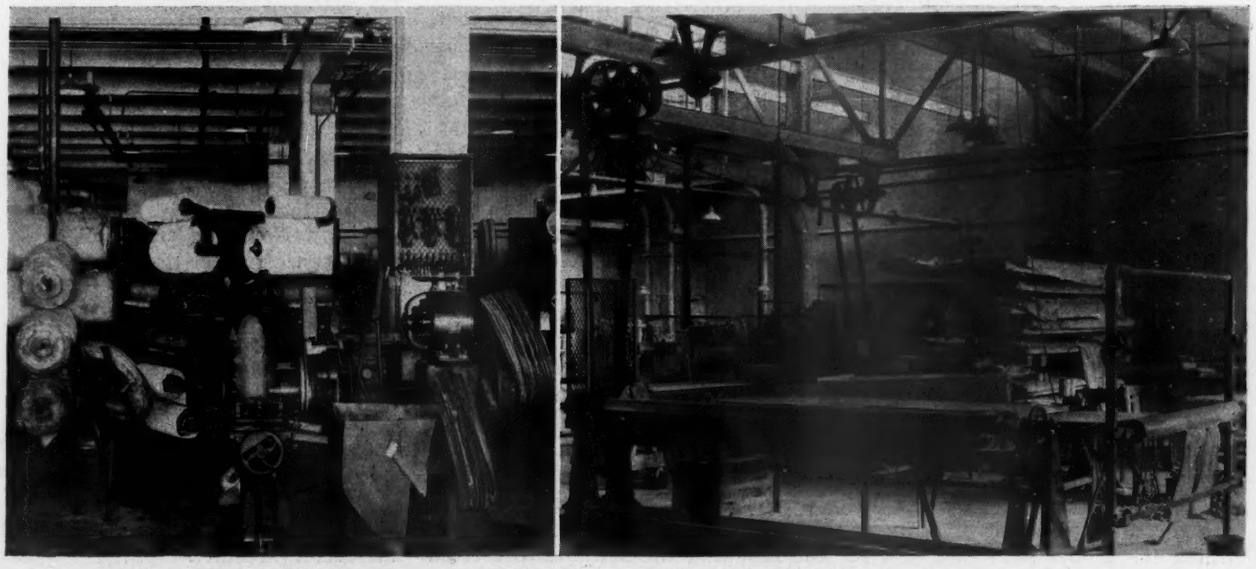
How Distribution of Light Is Affected by Changing Number of Lamps in a Bay

Lamps Per Bay	Minimum Intensity Ft.-Candles	Maximum Intensity Ft.-Candles	Ratio of Max. to Min. Intensity	Average Intensity Ft.-Candles
1	5.28	10.05	0.528	7.66
2	6.00	7.61	0.788	6.80
3	6.69	7.05	0.950	6.87
4	6.51	6.89	0.945	6.70

These tests were made under the following conditions: Bays 20 ft. by 20 ft., lamps mounted 9 ft. above working plane, in R. L. M. dome reflectors, and arranged symmetrically, with no obstructions to cast shadows.

General illumination of 5.5 ft.-candles is not sufficient for tire building, left, and tube wrapping, right.

Both of these operations also require that the light come from low angles, to facilitate close inspection. Over the tube-wrapping table two No. 815 X-ray reflectors with 200-watt lamps give an intensity of nearly 30 ft.-candles. This high level is necessary to avoid wrinkles in the wet, black fabric that is wrapped around inner tubes preparatory to curing them.



advantages overweighed the difference in cost.

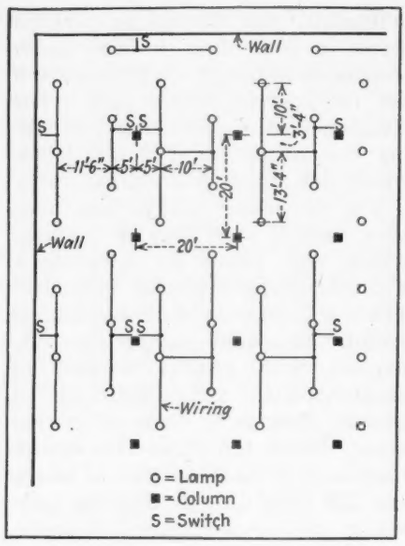
The size of transformer was set at 25 kva. in all cases for the regular lighting. The criterion for size is mainly the average size of the buildings to be lighted. The upper limit would be set by the amount of space that can be economically fed at 115 volts. Where the voltage drop is to be kept around 2 per cent, the maximum distance for the most economical transmission at 115 volts is from 50 to 150 ft., depending on the type of construction. Thus, where three- or four-story buildings are used and fairly high intensities arranged for, this limit is rather high. With transformers placed at the center of the long side of a rectangle, spaces 200 ft. by 100 ft. can readily be handled.

The structure of the 115-volt distributing system is always a subject of study and often one of special difficulty. The alliterative trinity of cost, convenience, and Codes is inextricably jumbled. There are two general schemes: central and distributed control. The first system has a main cabinet from which all the lights are controlled; in the second system the lamps are controlled locally by conveniently-placed switches. Both systems have their various modifications.

The advantage of the central control system is that all lighting is brought under the supervision of one person, which is very desirable under some conditions. It has, however, many disadvantages. With this system the leads from the transformers are run to a cabinet where each circuit is tapped onto a main bus through cutouts. The individual circuits may run to their respective distribution areas in any manner desired, conduit or open. The only reduction in wire size is in the main cabinet, where there are fuses to satisfy the Underwriters' requirements. Thus, we have of necessity longer runs of small wire and must use more copper to hold up the voltage. In general, the central control system is more expensive than the dispersed control system and can be justified only by the necessity of having the lighting under unified control or by Code requirements.

The advantages of the dispersed control system are lower cost of installation and the control of the lights by the workers themselves to suit their local needs. The difficulty with the dispersed control is in obtaining the proper reduction in wire size in an economical and practical manner without Code infringement.

In our case a main cabinet was placed just inside the wall from the transformers, which in all cases are hung on the outer walls of the buildings on steel platforms. In this cabinet is a fused main switch feeding a short copper bus and No. 4/0 risers which go up and down to other floors. These risers are fused, which



The lamps in two bays are controlled by one switch.

Study of all of the factors involved showed that the arrangement of switches and wiring shown here was the most economical. In this installation six lamps are controlled by one switch, except at the corners and near the walls, where the lamps are controlled in groups of two or three.

gives the first of a series of four reductions before the ultimate No. 14 conductor is reached. On each floor is a cabinet fed by the No. 4/0 riser, having two branch circuits of No. 2 conductor with fused switches. These No. 2 conductors are floor mains and run down the center of the building, one in each direction. Tapped onto these, through fused switches, are No. 8 mains running across the building. The individual lighting circuits are tapped to these No. 8 cross mains. Both the No. 8 and No. 2 mains are of triple-braid, slow-burning wire stretched open and suspended from the bottoms of the floor beams above.

One of the points of greatest conflict between cost, convenience and Codes in the open main system of lighting distribution is the run connecting the main with the circuit cutout.

Under ordinary operating conditions this section of wire between the fuse and the mains is protected by the branch fuse. The only situation under which protection is not afforded is when trouble occurs on this section itself. Owing to the shortness of the run and the fact that it is all in conduit, however, the chances of trouble here seem very remote. The only thing to be really feared is that in case of short-circuit on this section the wires in the drop might fuse and cause fire or other injury before the fuses in the mains would blow. In coming to a decision in the matter it was, therefore, finally agreed that the wire between the main and the fuse need be only large enough not to fuse at a current which would blow the fuses in the mains.

From the fuse on to the lights, excepting 10 ft. of conduit up the column, all the wire is No. 14 r.c. run open on cleats fastened to the ceiling. The 24-in. I-beam between the two bays on each circuit was passed by means of a short piece of conduit bent over the top of it and embedded in the floor above. Where the floor is concrete 4-in. by 4-in. wooden inserts were placed in it at every cleat position.

The voltage regulation is very close. The 2,300-volt lighting feeders are fed from a lighting bus through an induction regulator compounded for about 2 per cent line drop. Under the worst normal conditions the voltage at the lamps does not vary 2 per cent from the rated voltage.

Tests were made on the completed system with a Leeds & Northrup photometer. A bay was marked off into 2-ft. squares and readings were taken at the corners of each square. An interesting fact discovered was that only 51 per cent of the total light flux falling within a bay came from the lamps in that bay, while 49 per cent came from the lamps in surrounding bays. This was determined by taking a reading, first, with all lamps turned off except those in the bay concerned, and then with all lights on. In none of the tests, however, were lamps turned on at a distance greater than 40 ft. from the bay under test. The average illumination was found to be 5.05 ft.-candles and the ratio of minimum to maximum intensity was 0.78. This ratio figure shows the effect of columns and other obstructions. This scheme of general lighting with the addition of local lighting for inspection and other special work, has been used now for some time with very satisfactory results.

PRACTICAL operating data on leather belt drives, particularly information regarding their power-transmitting capacity under various service conditions which has been obtained from a series of extensive tests carried on at Cornell University by The Leather Beltintg Exchange Foundation, are contained in this article.

Tests which show

Capacity of Belts Under Operating Conditions

with particular reference to the relative power transmitting capacity of leather belts on vertical and angular drives

By R. F. JONES

Research Engineer, The Leather Belting Exchange Foundation, Cornell University, Ithaca, N. Y.

BELT drives, although by far the most common method of connecting two shafts or machines or the drive to its machine, are altogether too frequently laid out by rule of thumb or by guess. To provide reliable information, which could be used by practical operating men, on the power transmitting capacity of leather belts, The Leather Belting Exchange Foundation, has conducted a series of extensive tests on belts operating under various service conditions. The results obtained by some of these tests were given in an article* entitled "How Service Conditions Affect Belt Capacity," which appeared in the June, 1925, issue of INDUSTRIAL ENGINEER.

This previous article gave easily usable information that would assist operating men in laying out a belt drive and enable them to make the proper allowances for some of the conditions which affect its power transmitting capacity. Conditions tested and reported at that time covered the effect of diameter and ratio of pulleys, center distance, and high belt speed on horizontal belt drives, and also the use of the gravity belt idler. A large number of tests were made under a variety of operating conditions.

The results obtained from these tests were given in the form of curves and tables that indicated the power which various weights of belts are able to transmit at different speeds, and the correction factors which indicate the necessary allowances to be made for the types of drive indicated according to pulley size and distance between centers.

Since that time additional tests have been made to compare the power transmitting characteristics of belts operating horizontally, vertically, and at various angles with the horizontal. This information is incorporated in the present article to serve as a guide in the layout and design of these drives. In addition, the author has correlated the results with the method of belt drive design published previously so that this same system with the indicated modifications can now be used for vertical and angular drives.

Our regular 100-hp. laboratory apparatus, which was illustrated in the previous article, could not be used for this work without prohibitive trouble and expense; so parts of a smaller machine often used for demonstration work were employed. The principal units of apparatus used were, a 15-hp. electric cradle dynamometer, two 10-hp. electric motors, and a platform scale. This type of dynamometer is in such common use for absorbing and measuring power that a description of its construction and operation is unnecessary here.

One of the motors was mounted overhead on the platform scale, which was supported by an elevated platform about 8 ft. high, as shown in Fig. 2. Placing the motor on the scale provided a reliable means of measuring the belt tension, since any load registered by the scale beyond the tare weight of the motor and auxiliary apparatus was due to belt tension. Four especially designed jackscrews which allowed about 6 in. of vertical movement to provide for adjusting the belt tension supported the scale and motor. These jacks are operated from below by handwheels which cannot be seen in the picture.

In Fig. 2, the belt is driving vertically from the overhead motor to the dynamometer. The other motor,

Fig. 1—Angular drives were tested by raising the dynamometer and moving it to the side.

*Readers who do not have copies of the June, 1925, issue of INDUSTRIAL ENGINEER on file may obtain the information on which this previous article by Mr. Jones was based by requesting Report R-13 from The Leather Belting Exchange, 417 Forrest Building, Philadelphia, Pa.

shown on the left, was used to drive the dynamometer through a horizontal belt, at the same center distance and belt speed. In this way the belt could be changed from one drive to the other in a few minutes, and thus enable us to obtain a comparison of the two drives under the same conditions.

On the horizontal drive the belt tension was applied by weights which pulled on a cable attached to the motor. This cannot be seen in Fig. 2, but a track and two of the roller-bearing wheels will be noticed supporting the motor. Great care was taken to level the motor track so that the unweighted pan and cable would just balance the frictional forces on the wheels, thus insuring that no tension would be added to nor subtracted from the desired belt tension by gravity or friction.

This apparatus adapted itself very readily to tests at other angles than the vertical, because the dynamometer could be raised and moved to the left to give the required angle and center distance, as illustrated in Fig. 1. Tests were made in this way on belts operating at 45 deg. and 67½ deg. with the horizontal. The scale measured only the vertical component of the tension, and consequently the correct tension on the angular belts was obtained by using a scale setting equal to the sin of the angle times the desired belt tension.

Cast-iron pulleys 10 in. in diameter and with 4-in. faces, which had been well polished by usage, were employed. Both motors had a no-load speed of 1,200 r.p.m., and a full-load speed of 1,160 r.p.m., which gave a belt speed of between 3,100 and 3,200 f.p.m., depending on the load and slip.

Accurate slip measurement was accomplished through the use of our rotating-lamp slipmeter, which will be explained in detail for the benefit of those not familiar with the apparatus. Where the driver and driven pulleys are the same diameter, as in this case, a small brass plate is mounted on the fiber drum called the contactor, and this is attached to the motor shaft, as shown in Fig. 3. At one end of the dynamometer shaft is a black disk or dial upon which is fastened a flashlight bulb. Current is supplied to the bulb through slip rings and brushes as indicated, and the light will flash every time the contactor plate comes around to its brushes.

When the belt is running at no slip the two shafts will revolve at the same speed, and the light will always appear at the same point *0*. If belt slip is present, the dynamometer shaft will not revolve as fast as the motor shaft, so that when the motor shaft has made a complete revolution, the driven shaft has only reached position *1*, where the light flashes. The next revolution of the motor finds the light at position *2*. The distance from *0* to *1* and from *1* to *2* is the slip during each revolution. These distances are, of course, exaggerated in Fig. 3 to emphasize the principle of the slipmeter.

In use, the machines are running so fast that the light appears as a streak, which moves whenever slippage occurs. Every revolution of the light indicates the loss of a revolution through slip. Dividing the r.p.m. of the light by the r.p.m. of the driver and multiplying by 100 gives the percentage of slip.

Procedure Followed in Making Belt Drive Tests

Two different high-grade leather belts were used in these tests as a check on the accuracy. In addition, similar tests were also made on belts of other materials, but the results and curves obtained are not included in this article. A few tests were made on the flesh sides of the leather belts for comparison between the vertical and horizontal drives. The dimensions of the two belts are approximately as follows: Belt No. 1 was 1 in. wide, 0.204 in. thick and

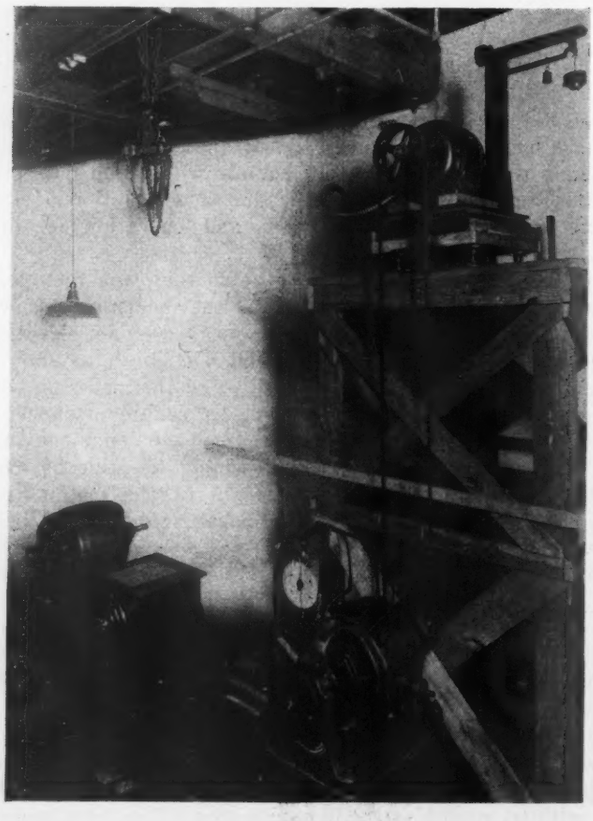
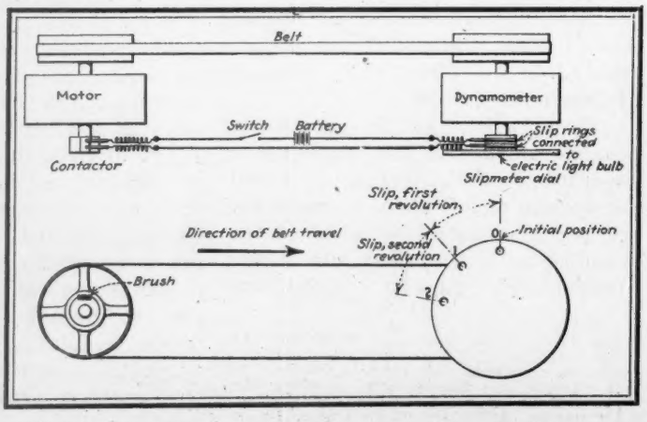


Fig. 2—Tests were first made on horizontal and vertical belts with the apparatus set up as shown.

The dynamometer is located in the lower foreground and can be connected by the same belt either to the motor on the scales on the platform to operate as a vertical drive or transferred quickly to the motor at the left to operate as a horizonal drive. The apparatus is so designed that all conditions can be kept constant, and as the change can be made in a few minutes the results are comparable.

Fig. 3—Slip is measured by this rotating-lamp slipmeter when the pulleys are of the same diameter.

A flashlight bulb is mounted on the black dial and connected through brushes and a special commutator on the motor shaft to light at each revolution. If there is no slip the light will remain at the initial position *0*. Due to the slip the light travels to position *1*, then to *2*, and on around: each revolution of the light indicates the loss of a revolution through slip.



weighed 15.2 oz. per sq. ft.; belt No. 2 was 0.965 in. wide, 0.19 in. thick and weighed 14.85 oz. per sq. ft.

These belts had been used previously for other work and therefore were well run in. It is necessary before any tests are made that each belt be run long enough to be sure that its surface condition is constant, or nearly so.

The belt tension was set when the test belt was running at normal speed under no load. We have designated this as "the light-running tension" (*L R T*) to differentiate it from the "initial tension" which is set with the belt at rest, or "the slow-running tension" which is set while the belt is running very slowly.

Three light-running tensions were used in most of the tests: namely, 50, 75, and 100 lb., which range was great enough to show the effect of tension under the various conditions. The tension in each individual strand was one-half of the light-running tension.

The tests were divided into two groups: First, a series on belt No. 1, which were made primarily to compare the power transmitting characteristics of the horizontal and vertical drive; second, tests on belts Nos. 1 and 2 which were made to compare the 45-deg. and 67½-deg. drives with the horizontal and vertical drives. A *test* consisted principally of slip readings taken as the load was increased in increments until the maximum capacity of the belt had been reached. Care was taken to maintain the room temperature practically constant, and the relative humidity was measured at frequent intervals.

With the first group of tests, which compared the horizontal and vertical drives, we made tests on one of the two drives at the three light-running tensions, and then immediately changed the belt to the other drive and repeated the three tests. This method eliminated the possibility of error due to surface or humidity changes. Five series of comparative tests were made in this way. All horizontal belt tests were made with the tight side on the bottom and all comparisons of the different drives will be made on a tight-side-below basis.

The second group of tests, which investigated angular drives, had to be handled in a little different way. Here the apparatus was first set up to run the belt at 45 deg. and tests were made on belt No. 1 at each of the three tensions with the tight side of the belt on top and then on the bottom. Tests comparing the tight side above and below were made directly following one another. Then the dynamometer was moved to give a 67½-deg. drive and the tests were repeated. Following these, vertical and horizontal drive tests were made to get a basis for comparison of results under practically the same operating conditions.

Careful analysis of the data obtained on the first tests revealed inconsistencies which could not be entirely explained; so more tests were made on belt No. 2, in the same way as before except that the tight-side-above tests on the angular drives were omitted. A few additional tests, made principally to check the accuracy of the apparatus, completed the work.

Table II—Effect of Center Distance on Horizontal Drives

Center Distance in Feet	Per Cent Difference
5	6
10	15
15	19
20	21
25	23

Per cent difference= $[(H\text{-}V) \div H] \times 100$.

Preliminary Discussion of Results Obtained

A total of 88 tests were made during the progress of the investigation. As it is impracticable in this report to show curves for all of these tests a few representative curves have been selected as illustrative of the results obtained. Figs. 4 and 5 show the transmission characteristics of a leather belt (grain side) and a leather belt (flesh side) on the horizontal and vertical drives. Figs. 6 and 7 are given as typical curves of a leather belt (grain side) running at 67½ deg. and 45 deg. with the horizontal. These will be discussed in detail later. The following nomenclature has been employed in marking the curves:

67½ deg.=Belt running at an angle of 67½ deg. with horizontal.
H=Belt running horizontally.
V=Belt running vertically.
45 deg.=Belt running at an angle of 45 deg. with horizontal.
T_1-*A*=Tight side of belt on top.
T_1-*B*=Tight side of belt below.

Unless a curve is marked T_1-*A*, it is understood that the tight side of the belt was on the bottom. Each curve is labeled with the *L R T* (light-running tension). On all curves, the horizontal axis indicates the percentage of slip, and the vertical axis the horsepower transmitted.

Considering first the horizontal and vertical drive comparisons as shown in Figs. 4 and 5, the horizontal drive (using T_1—the tight side below) transmitted more power than the vertical drive in every case, the difference depending on the side of the belt used and the tension. The superiority of the horizontal drive becomes less pronounced as the tension is increased.

There is not much difference in capacity at slips below 2 per cent with a high-capacity leather belt such as No. 2, Fig. 4, because most of the slip up to this point consists of creep, which is due to elasticity and is practically the same on either

Table I—Comparison of Tests on Horizontal and Vertical Belt Drives

Belt	Surface Against Pulley	LRT	Per Cent Slip 1.5 Hp. Hor.	1.5 Hp. Vert.	1.5 Per Cent Diff.	2 Hp. Hor.	2 Hp. Vert.	2 Per Cent Diff.	3 Hp. Hor.	3 Hp. Vert.	3 Per Cent Diff.
No. 1	Grain	50	5.55	5.10	8.10	6.85	5.6	18.2	7.6	6.0	21.0
No. 1	Grain		5.2	5.0	3.8	6.75	5.9	12.6	9.3	6.3	32.2
No. 2	Grain		5.10	4.75	6.9	6.6	6.0	9.10	9.05	6.7	26.
No. 2	Grain		5.25	4.9	6.7	6.75	6.05	10.4	9.75	6.55	32.8
No. 2	Flesh		3.7	3.10	16.2	3.97	3.28	17.4	4.15	3.47	16.4
No. 1	Grain	75	6.7	6.3	6.0	8.45	7.75	8.28	10.3	8.7	16.0
No. 1	Grain		6.2	5.9	4.85	8.05	7.5	6.83	11.1	8.9	19.8
No. 2	Grain		5.75	5.6	2.6	7.3	7.25	0.68	10.2	9.2	9.85
No. 2	Grain		5.9	5.65	4.23	7.5	7.2	4.0	10.5	9.1	12.9
No. 2	Flesh		4.82	4.5	6.63	5.15	4.83	6.2	5.55	5.2	6.3
No. 1	Grain	100	7.35	7.15	2.7	9.2	8.9	3.26	11.5	11.0	3.9
No. 1	Grain		6.95	6.75	2.9	8.85	8.55	3.4	11.5	11.0	4.3
No. 2	Grain		6.6	6.47	2.0	8.27	8.10	2.10	11.2	10.5	6.0
No. 2	Grain		6.6	6.45	2.3	8.35	8.2	1.8	11.6	10.9	6.10
No. 2	Flesh		6.0	5.9	1.7	6.45	6.35	1.5	6.98	6.9	1.1

drive for the same load. Obviously any comparisons on this type of belt must be made at 3 per cent slip or more. With the lower-capacity belts, such as the flesh side of belt No. 2, creep alone persists only up to about 0.5 per cent slip beyond which point true slip commences and the curves separate. A good comparison of the two drives with the flesh side against the pulley may be made at 1½ to 2 per cent slip.

Table I gives the horsepower transmitted at 1.5 per cent, 2 per cent, and 3 per cent slip at each tension for each belt tested on the horizontal and vertical drives, including those made in connection with the angular drive tests. These values were picked from the horsepower slip curves, all of which are not included here.

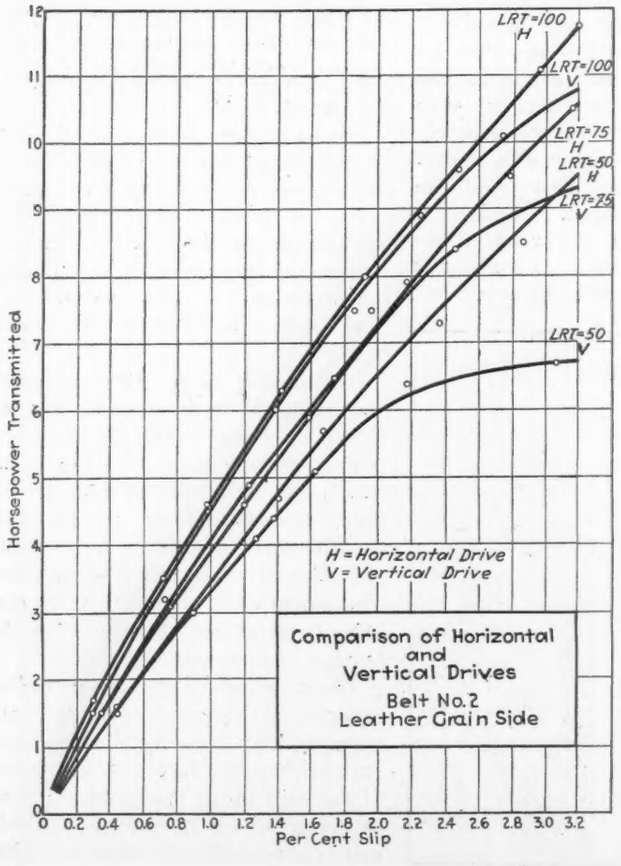
Most of the conclusions from this table will be based on the horsepower transmitted at 3 per cent slip. At the medium tension (75 lb. *L R T*) with the grain sides of the two belts to the pulley, the horizontal drive transmitted an average of 14.6 per cent more power than the vertical drive; in the one flesh side comparison the difference was 6.3 per cent. Since 75 lb. is slightly above the average tension, perhaps it would be well to examine the results at 50 lb. *L R T*. Here the horizontal drive with the grain side to the pulley gave an average of 28 per cent more power, and a superiority of 16 per cent in the one flesh side comparison. After weighing these results in conjunction with those from several tests not given here, our general conclusion is that a leather belt for a vertical drive at the test center distance (7 ft. 6 in.) should be about 12 per cent wider than for a corresponding horizontal drive. The difference at other center distances is given in Table II.

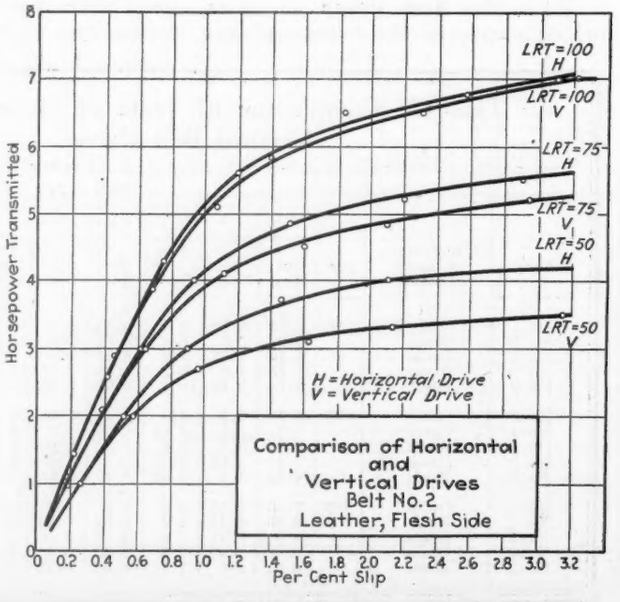
The problem of the center distance is of considerable importance because the transmission capacity of a vertical belt does not increase with the center distance as does that of a horizontal belt. The operation of a vertical belt is the same as a horizontal belt in that as the load increases, the belting material under tension on the tight side is worked over to the loose side, which reduces the tension on this side. However, the loose side of a horizontal belt can take care of additional length by sagging without much reduction of the loose side tension, while the loose side of a vertical drive must take care of it by shortening up an amount equal to the additional length from the tight side.

A point is soon reached with the vertical belt, when any further shortening of the loose side would result in zero tension on this side, and further increase in load or tension would cause the belt to fall away from the lower pulley. This is the absolute theoretical limit of transmission for any vertical drive. Practically, when the slack side tension is reduced to a certain value

Table III—Horsepower Transmitted at 3 Per Cent Slip on the Angular Drives

General Data			67½ Deg. Drive			45 Deg. Drive		
Belt No.	Chart Fig. No.	LRT Lb.	T_1-B Hp.	T_1-A Hp.	Diff. Per Cent	T_1-B Hp.	T_1-A Hp.	Diff. Per Cent
1	6 & 7	50	7.2	6.75	6.25	9.13	7.75	15.1
1	6 & 7	75	9.7	9.35	3.60	12.0	10.45	12.9
1	6 & 7	100	12.15	11.20	7.80	12.8	11.50	10.1





Figs. 4 and 5—The difference in transmitting capacity of horizontal and vertical belts is well shown here. The different results obtained by driving with the grain (Fig. 4) and flesh (Fig. 5) sides next to the pulley clearly indicate the advantage of using the grain side.

the belt slips badly, and this is the actual limit of transmission. It is obvious that, since the horizontal belt can compensate for the extra length by sagging on the loose side while the vertical belt can not, the horizontal belt ought to transmit more power.

From the above analysis, it can be readily seen that the capacity of a vertical drive depends on its ability to shorten up on the loose side. If the center distance is doubled, then there will be twice as much extra length passing over to the loose side, for any given load, but there will also be twice as much shortening of the loose side, so the slack side tension will remain the same. It follows, therefore, that the power transmission of a vertical belt is independent of center distance, except for the effect of the additional weight of a longer belt, which is practically negligible.

As the horizontal belt capacity increases with the center distance, while the vertical belt capacity does not, there will be a greater percentage difference between the power transmission of the two belts at long center distances than at short ones. Using the relation between the center distance and transmission capacity of a horizontal drive given in Fig. 9 as a guide, Table II has been prepared to show approximately what the rated capacity difference of the two drives would be at other center distances. The right-hand column gives the percentage difference based on the horizontal belt rating, which is greater. Although Table II can be used for belt design work, this information may be applied more easily to actual belt problems by using the method of design and the necessary charts given later in this article.

It is apparent that the vertical belt is more sensitive to tension changes than the horizontal belt. The charts reproduced here as Figs. 4 and 5 show a greater reduction in transmission capacity with the vertical belt as the tension is reduced. The gradual drop in tension of a factory belt would cause a similar drop in capacity, and probably it would have to be retightened more often than a horizontal belt to maintain its rated capacity.

Some of the tests on the angular drives at 67½ deg. and 45 deg. with the horizontal were a little confusing, because certain belts at the 100 lb. *L R T* transmitted more power on the 45-deg. drive than they did on the horizontal drive. Later a careful check at this tension indicated that there is little difference in the transmitting characteristics of the two drives. At the two lower tensions the transmitting abilities rated in the following order in most of the tests: first, horizontal belt; second, 45 deg. belt; third, 67½ deg. belt; and fourth, vertical belt.

Two sets of curves, Figs. 6 and 7, illustrate the general characteristics of the angular drives. In every case, more power was obtained with the tight side of the belt below but there was less difference between these two conditions at 67½ deg. than at 45 deg. Thus, as the vertical is approached, the difference becomes less, and reaches zero at the vertical. Another general characteristic which can be seen from these curves is that as the tension is increased, the 45-deg. and 67½-deg. drives perform more nearly alike. This is in accord with a similar conclusion reached concerning the horizontal and vertical drives and it applies to all the drives.

The values in Table III, which compares the power obtained from the 67½-deg. and 45-deg. drives with the tight side above and below, were taken from Figs. 6 and 7.

Figs. 6 and 7—The effect of angular drives on transmitting capacity, as shown by these charts, is discussed fully on this and the following page.

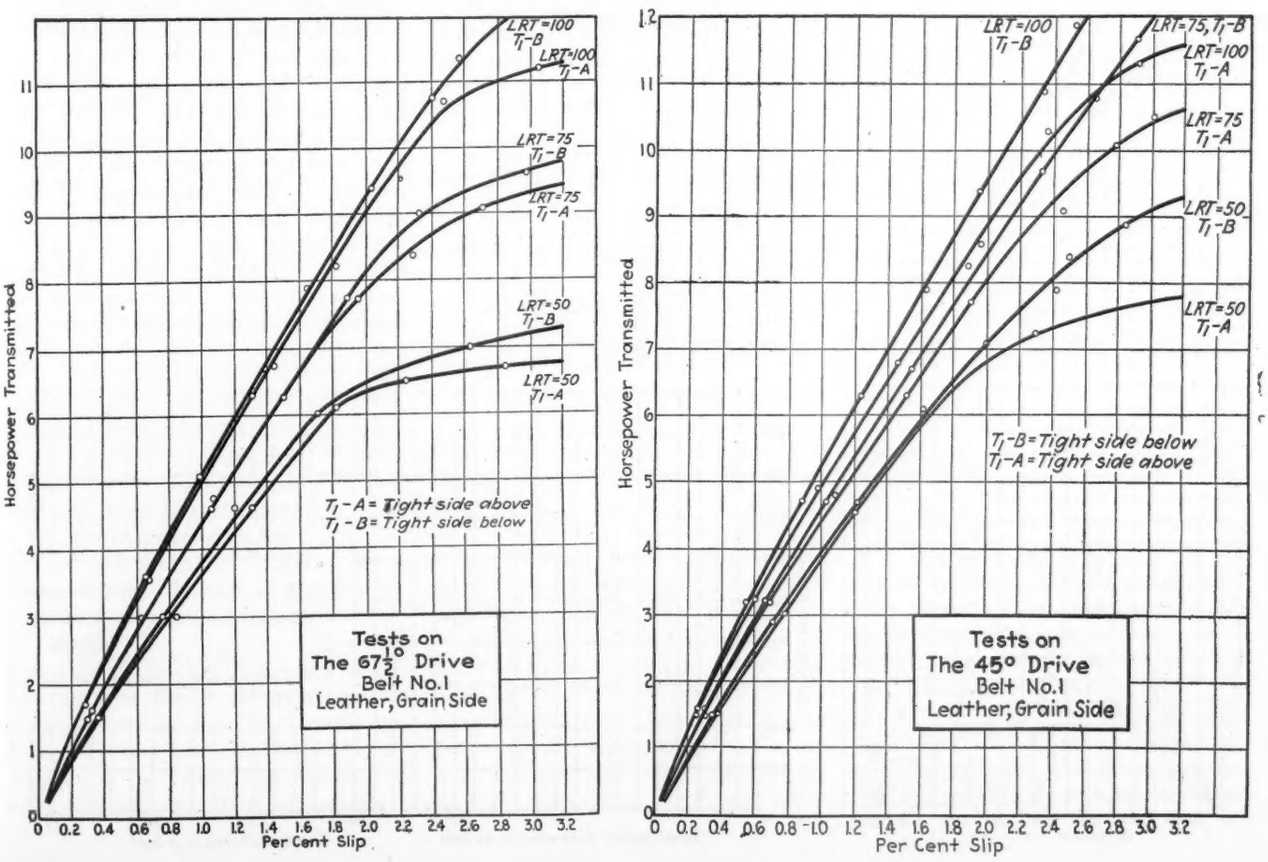


Table III can be studied more easily than the curves and if desired it can be compared with Table I on horizontal and vertical belts. Under average tension conditions a 67½-deg. drive, having its tight side below, will transmit about 6 per cent more power than with the tight side above. The difference will remain about the same for all ordinary center distances, say up to 20 ft. On the 45-deg. drive this difference in transmission is about 12 per cent for the center distance used, but it will increase some with longer center distances, probably about the same as with a horizontal drive.

For all practical purposes the 45-deg. drive may be rated the same as the horizontal drive, if the tight side of the belt is below, while if the tight side is above, the rating for a 45-deg. drive should be a little less than for a corresponding horizontal drive. The 67½-deg. belt with the tight side below should be rated about halfway between the horizontal and vertical drives, and when the tight side is above, the rating ought to be that of a similar vertical drive.

The results and conclusions from these experiments have been correlated with the curves for belt design which were given in the previous article and are repeated here as Figs. 8 and 9. The following recommendations are made for the design of vertical and angular drives by this method.

(1) For vertical drives, and for angle drives between the vertical and 45 deg. with the *tight side above*, use a correction factor of 0.765 multiplied by the correction factor for pulley size from Fig. 9. The product of these two factors should then be multiplied by the horsepower ratings from Fig. 8 to obtain the corrected horsepower per inch of width. No correction factor is needed for center distance.

(2) For angle drives with the *tight side below* between the vertical and 67½ deg., use the method given above under (*1*) above.

(3) For angle drives with the *tight side below* between 67½ deg. and 45 deg. use a constant correction factor of 0.815 instead of 0.765 and proceed as directed under (*1*). No correction factor for center distance is needed as the figure 0.815 takes its place.

(4) For angle drives between 45 deg. and the horizontal, with the tight side above or below, use the method of design as explained at length in the caption in connection with Figs. 8 and 9.

Some may have doubt as to the accuracy of work done on belts as narrow as 1 in. and the reliability of assuming that results obtained on such narrow belts are applicable in direct proportion to the width on wider belts. Some time ago we made a careful investigation of the relative capacities of belts of different widths and found that the transmission capacity varied directly with the width of the belt. Furthermore the author has since had many opportunities to check this law with leather and other kinds of belts and has always found it to be correct. The absorbing dynamometer and tension scale are smaller and more accurate than those on larger apparatus. Therefore, we are fully convinced that the conclusions drawn from this work are reliable.

Figs. 8 and 9—These curves are used in conjunction to obtain correction factors for determining allowances, because of center distance, pulley size and whether the tight or loose side of the belt is on top, when laying out a belting installation.

In the use of these charts the following precautions must be observed: (*a*) These charts are to be used only on horizontal or approximately horizontal drives. (*b*) Do not use Fig. 8, at left, without the correction from Fig. 9, at right. (*c*) The diameter of the larger pulley should not be more than six times the diameter of the smaller one. To use these curves, with these three points in mind, proceed as follows:

(1) Find the correction for center distance from one of the two center-distance curves, depending on whether the tight side is above or below. If the center distance is greater than 25 ft., use the correction for 25 ft.

(2) Find the correction for pulley size from the pulley-size curve, Fig. 9, using the diameter of the smaller of the two pulleys. If both pulleys are larger than 36 in. in diameter no correction is necessary.

(3) Choose the curve, Fig. 8, at left, corresponding to the desired weight of belt, and take from it the horsepower per inch of width according to the belt speed used.

(4) Multiply the result of (*1*), (*2*) and (*3*) together to get the corrected horsepower per inch of width.

(5) Divide (*4*) into the total horsepower to be transmitted to get the correct width of the belt.

As an example, suppose a 10-in. pulley running at 1,000 r.p.m., giving a belt speed of 2,600 ft. per min., is to transmit 15 hp. to a 36-in. pulley at a center distance of 8 ft. Assuming the tight side is below, what size of heavy single belt is required? Carrying the computations through in the same sequence as indicated, the procedure is as follows:

(1) The correction factor for 8 ft. center distance with T_1 (the tight side) below is obtained from Fig. 9 and equals 0.87.

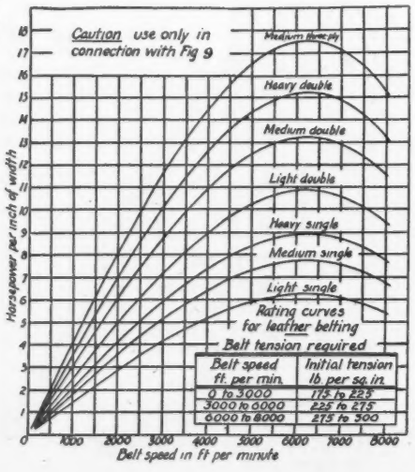
(2) Correction factor for 10-in. pulley size from Fig. 9 equals 0.853.

(3) Horsepower per in. width, from Fig. 8, at belt speed of 2,600 ft. per min. for heavy single belts=5.25.

(4) Multiplying, $0.87 \times 0.835 \times 5.25 = 3.9$ horsepower.

(5) Divide 15 by 3.9=3.85, width of belt. Therefore, use a 4-in. heavy single belt.

When the width of belt comes out an uneven size such as 3.85 in. the next larger size should always be chosen. A table of the initial tensions required for different speeds is given in Fig. 8. The tensions are given in pounds per square inch of cross-sectional area per strand of belt. The cross-sectional area is obtained by multiplying the width times the thickness, so a belt 4 in. wide and 0.2 in. thick would have a cross-sectional area of $4 \times 0.2 = 0.8$ sq. in. If the recommended tension is 175 lb. per sq. in., the tension per strand on this belt would then become $0.8 \times 175 = 140$ lb.


Caution use only in connection with Fig 9
Medium triple ply
Heavy double
Medium double
Light double
Heavy single
Medium single
Light single
Rating curves for leather belting
Belt tension required
Belt speed ft. per min. | Initial tension lb. per sq. in.
0 to 3000 | 175 to 225
3000 to 5000 | 225 to 275
5000 to 8000 | 275 to 300
Horsepower per inch of width
Belt speed in ft per minute

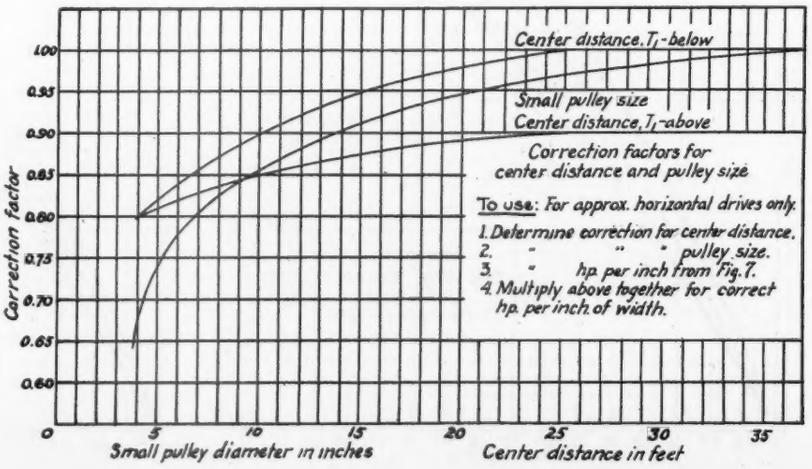

Center distance, T_1 - below
Small pulley size
Center distance, T_1 - above
Correction factors for center distance and pulley size
To use: For approx. horizontal drives only.
1. Determine correction for center distance.
2. " " " pulley size.
3. " hp per inch from Fig. 7.
4. Multiply above together for correct hp. per inch of width.
Correction factor
Small pulley diameter in inches
Center distance in feet

Fig. 1—A single unit charger is used continuously at this plant. This Mercury tractor is provided with two batteries, one of which is on charge while the other is in use. This permits 24-hr. operation of the tractor. Note the convenient caster-mounted table for receiving the Edison battery as it is pulled out of the tractor and for holding it during the charging process. The interior of the control panel is shown in Fig. 8 and the connection scheme for it is shown in Fig. 9.

Some of the factors to be considered when

Selecting Storage Battery Charging Equipment

with a discussion of the charging requirements of lead and alkaline batteries, and characteristics of equipment best suited to industrial use

BY JOHN H. HERTNER

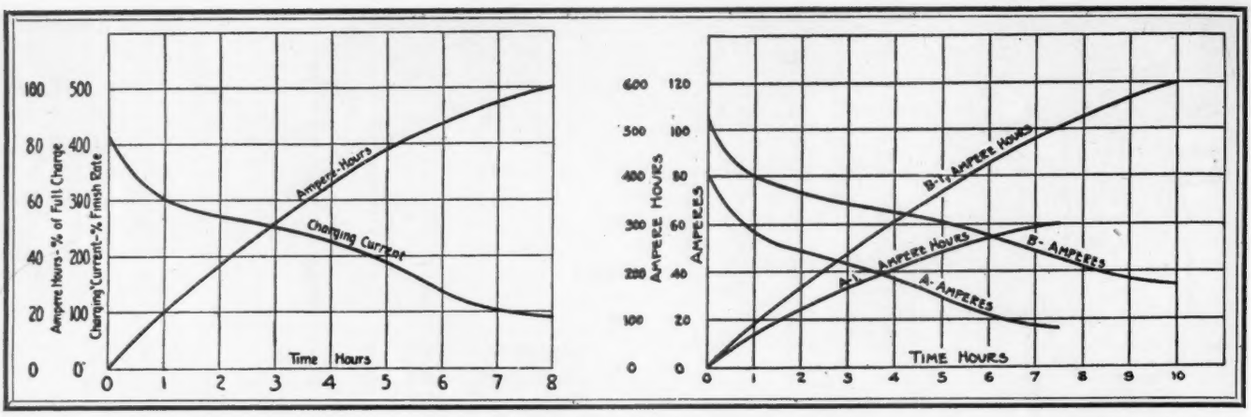
President, The Hertner Electric Company, Cleveland, Ohio

FROM late in the nineties until about ten years ago the number of electrically-driven passenger carriages in use gradually increased in number. Since that time, however, there has been a diminution in their use until they have all but disappeared.

In the meantime the industrial tractor and truck have demonstrated their worth. From a comparatively small number in 1915, the number of trucks and tractors in use has steadily grown and they are establishing new fields of usefulness in places where only a short time ago manual labor was ineffectively employed at probably ten times the cost. Go into the plant of an industrial truck manufacturer at any time and you will be able to see a new model, specially designed to replace hand labor and for doing some special work more quickly, more effectively, and more cheaply.

The electric road truck, too, is making steady progress. Although its advance has not been so rapid as that of the industrial type, the electric road truck is considered superior to the gasoline truck for hauling that does not involve long distances at high speeds. On account of its ease of handling, the electric commercial truck will often accomplish much more work in a given time.

During the period when the pleasure car was the principal user of charging current the matter of battery charging was on a much less scientific basis than it is today. The car was generally charged either at home or in one of the many public garages. If charged at home, the owner put the plug into the receptacle on the car, closed the switch and permitted the unit to take care of itself. The charging rate generally dropped to a point so low that if it remained connected beyond the proper point of battery charge, the cells were not injured nor did the owner inquire about the extra energy consumed. As a rule the time available for charging was more than ample, so that the rate from start to finish could be low. Usually the battery could be charged for 12 hr. The car that was run



Figs. 2 and 3—Performance of charging equipment for lead battery service.

In Fig. 2 are shown the charging current curve and ampere-hour curve for a single-unit charger. Fig. 3 shows the curves for a dual-unit charger. *B* and *B-1* are the charging current and ampere-hour curves, respectively, when the unit is charging two batteries simultaneously. *A* and *A-1* are the performance curves after one battery has been cut out.

late in the evening was generally not wanted until noon and the one that had to go out early in the morning had not been used late the evening before. If the car was charged in a public garage, the same conditions held except in those places where an attendant made the rounds periodically, taking gravity readings and readjusting the ballast resistance. If the car was not properly charged it was considered simply as an unavoidable accident which was to be expected.

With the coming of the industrial truck and the passing of the electric pleasure car, conditions are somewhat different and the need of reliable charging apparatus and methods has become more imperative. A truck held out of service unexpectedly may disturb the output of an entire factory and it is essential that every effort be made to avoid any tie-up in truck operation.

The thing that gives life to the truck is the battery, and the battery in turn depends for its life upon the charging equipment. Both alkaline and lead batteries, each of which has its advantages, are being used in increasing numbers. The two types must, however, receive considerably different treatment in charging. To get the best results, the alkaline type must be charged at an ampere rate about the same as its average working discharge rate. The lead battery, on the other hand, demands a charging rate that is quite low at the finish, but which may be extremely high at the start. This rate is sometimes defined by the statement that "the rate in amperes at any stage of the charge may be as high as the ampere-hours still remaining to be put into the battery." Hence, since the rating of a battery is generally given as a certain ampere rate over a period of from four to six hours the starting rate of charge may be from four to six times the normal discharge rate.

At first glance, it would appear that for charging a lead battery a constant-potential source would be preferable, because during the charging process there is a rise in battery potential, dependent on the charging rate and other factors, which may be roughly set at 15 per cent and which on a constant-potential source will aid in reducing the ampere rate as the battery becomes charged. This is just what a lead battery should have, but it is not suited for alkaline batteries which, as above stated, should have a uniform charging rate and, therefore, a constant-current source of charging energy.

Under these conditions several systems of charging have sprung up in an attempt to make existing constant-potential sources of current fit the needs of the battery.

Street trucks were largely standardized to fit 110-volt service with about 40 cells of lead battery or 60 cells of alkaline battery so that only a small amount of the energy used in charging would be wasted in the ballast resistance. When the

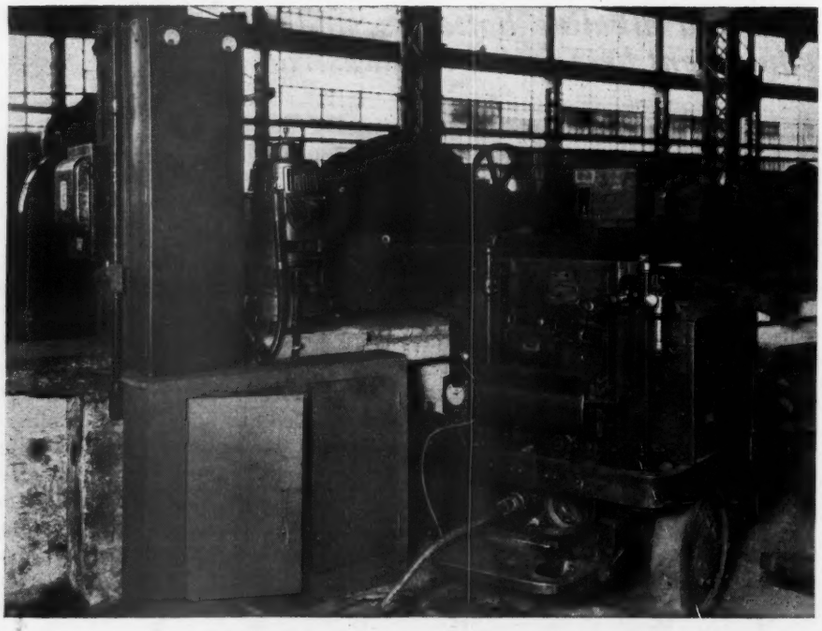
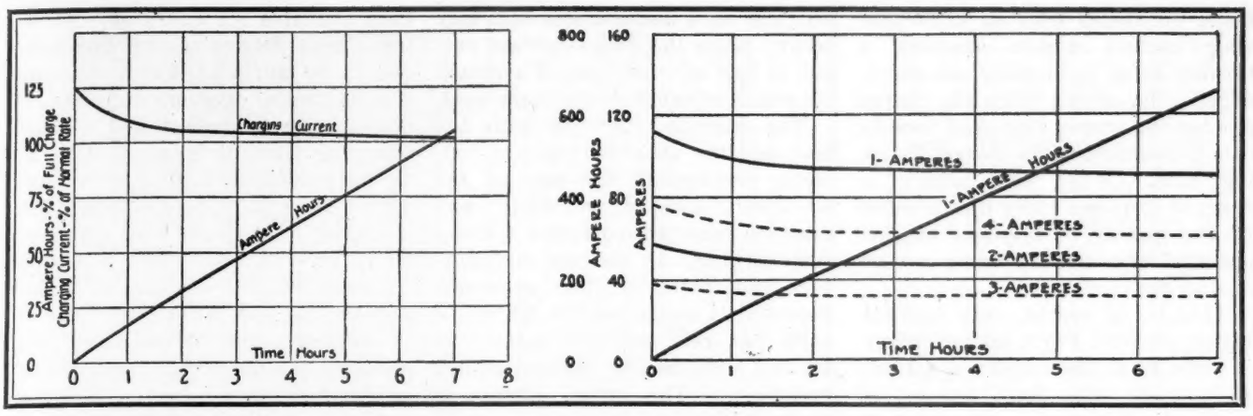


Fig. 4—Dual unit charger for use on industrial trucks.

This is an installation of Hertner charging equipment in the plant of the Whiting Corporation at Harvey, Ill. It is capable of charging two sets of 12-cell, 21-plate batteries simultaneously and is shown charging an Exide Ironclad battery in a Baker R & L lift truck. Notice the Sangamo ampere-hour meter mounted on the front of the truck so as to give the driver an indication of the condition of the charge in his battery.



Figs. 5 and 6—Different characteristics are required of the charging equipment for alkaline batteries.
Fig. 5 shows the characteristics of a single-unit charger, while Fig. 6 is for a dual-unit charger. The dotted curves in Fig. 6 show the result of setting the field regulator to charge simultaneously two batteries of unequal capacity and requiring different charging rates.

industrial truck and tractor were introduced these standards were not followed, for lower voltages were adopted. This may be traced to a number of causes.

First, one of the earliest applications of industrial trucks was for the moving of baggage in railway stations. Here batteries which are standardized at 24 volts on discharge are also used in car lighting and it was convenient to use the same charging facilities for both types of batteries.

Second, with the smaller watt-hour capacity required in the industrial truck it was found advantageous to use fewer cells, rather than to retain the same number of cells and use a smaller size. With the same watt-hour capacity the larger cells occupy less room; and space is at a premium in industrial vehicles. As an illustration compare 40 cells of 7-plate Exide Ironclad battery with 20 cells of 13-plate Exide Ironclad battery. Both batteries are rated the same in watt-hours, being 7,560 on a 4½-hr. basis, and can consequently do the same work. As to the space occupied, however, the 7-plate battery occupies approximately 14 per cent more space than the 13-plate unit, weighs 11 per cent more, and costs more. Similarly with the Edison battery, comparing 40 cells of the size A-4 with 20 cells of the A-8 size each has a capacity of 7,200 watt-hours on a 5-hr. basis, but the 40 cells of A-4 can be put into four standard crates of 10 each while the 20 cells of A-8 can be put into four standard crates of 5 each. These crates will be about 12 per cent shorter than the A-4 crates, but of the same width and height. The A-8 battery weighs somewhat less and also costs less.

Aside from this, there is a decided advantage in the use of the lower voltage in that there is less electrical leakage which, particularly in the case of some of the older assemblies of lead batteries, was often quite troublesome. Offsetting this, however, with the lower voltage there is the necessity of using heavier wiring in order to avoid excessive copper losses, for with the voltage cut in two the current is doubled so that the resistance of the wiring must be quartered, which means that the copper cross-section must be increased fourfold. In addition, this lower voltage requires larger commutator surface and the size of the controller fingers must be increased, both of which add to the expense. Apparently, however, these disadvantages are more than balanced by the advantages.

No definite standard voltage for industrial truck use has been adopted to date and the possibility of such standardization seems remote. Where the service is fairly light and where more speed is required it is an easy step to substitute 15 smaller cells for 12 cells of a certain size, thereby giving the vehicle the required speed, and although this cuts down the mileage per charge, yet it increases the daily radius because of the decreased running time per trip. This, of course, changes the charging conditions.

As matters stand today most industrial trucks operate on from 6 cells of lead-type battery or 12 cells of Edison alkaline battery as a minimum, to 24 cells lead or 42 cells Edison as a maximum, with any one of a number of intermediate points.

Under such conditions charging from 110-volt direct-current power is extremely inefficient, unless the cost of power need not be seriously considered. If for example, 12 cells of 15-plate Exide Ironclad battery are to be charged the actual energy required to fill them would be about 7,000 watt-hours which, at a cost of five cents per kw-hr. would cost 35 cents. However, the energy wasted in the ballast rheostat is approximately three times as great and would cost approximately 95 cents, which is quite an item. If, on the other hand, the power cost is only one cent per kw.-hr. the cost of the useful energy put into the battery is seven cents, while the energy lost in the ballast resistance is reduced to 21 cents. Were the line service 220 volts the losses would be more than double, totalling $2.20, approximately.

Further, when thus charging through a fixed resistance, the current would be of almost constant value. This is apparent since the current would be determined by the difference between line and battery voltage, and on a 110-volt line and a 12-cell battery this would be approximately $110-(2.15\times12)=84$ volts at the start and $110-(2.6\times12)=79$ volts at the end of the charge, or a total drop of only 8 per cent.

In order, then, to charge a lead battery within a reasonable time, keeping the finish rate within safe limits, it is necessary to vary the resistance either manually or by some automatic means. The time-honored rule, which was generally found engraved on the nameplate of the battery, was to charge at a rate which, if held continuously, would completely charge it in about 5 hr. until active gassing began, when this charging rate was reduced to about one-third of the former rate.

This is automatically accomplished through the use of an ampere-hour

meter furnished with an extra gassing contact which operates a breaker so as to increase the resistance in the circuit when the charge reaches the proper stage and thereby cuts the current to the correct finishing rate. When the battery is charged it is generally disconnected by the opening of a second breaker operated by a corresponding contact on the meter.

This is, of course, only approximately correct. For a proper charge, in order to fill the battery as quickly as possible with least amount of gassing and heat, the charging rate should fall from the start until the finishing rate is attained. Rapid gassing indicates a loss of energy, for the gas given off is the result of the decomposition of the water of the electrolyte, instead of having the current absorbed in altering the chemical condition of the plates. Incidentally, rapid gassing has the effect of loosening the active material and shortening the life of the plates.

For charging the Edison battery, a direct-current source requiring a large voltage drop in the ballast resistance is admirably suited. For example, with 21 cells of Edison battery to be charged from a 110-volt line, the initial voltage of the battery would be about 33 volts and the final voltage would be 38 volts, with a current drop from start to finish of only about 8 per cent. This, however, does not alter the fact that such charging is extremely wasteful of electrical energy and the loss is serious where the cost of power is at all high.

In all cases where alternating current only is available it is necessary to use a transforming device. A very dependable type of such device for batteries of the size under consideration is the motor-generator unit. All power lines are subject to disturbance and in the case of alternating-current service there are possible variations both of voltage and frequency, and the characteristics of a motor-generator set are such as to transmit to the least extent any such disturbances that may occur; hence the direct-current output is less affected than if a rotary converter or other device were used.

The manufacturers of both the lead and the alkaline types of batteries recommend the use of the so-called constant-potential and modified, constant-potential systems for charging. In the case of charging lead batteries, the generator potential is maintained at 2.3 to 2.4 volts per cell and the battery is thrown onto the line without ballast resistance. The initial current is high and some care must be exercised to meet the needs of the room temperature, and consequently that of the battery. Individual batteries also show differences in finish voltage due to differences in age, density of electrolyte, type of plate, and other similar conditions.

With the alkaline battery there is no real equivalent to the above, because a ballast resistance must always be used where constant line potential is applied. It might be added here that when a lead battery has been allowed to sulphate, it is necessary to use a higher voltage to break down the resistance of the plates and 2.4 volts per cell is not a sufficiently high voltage for this duty. This, along with the facts already mentioned, makes the modified, constant-potential system more desirable.

With the modified, constant-potential system a ballast resistance is used, the amount of which is dependent on the number of cells in series, the size of the cell, and the time available for charging. These items also determine the line voltage to be applied. From the constant-potential system on one extreme, with no ballast and a short charging time, it is possible to go to an extremely high line voltage with a large ballast resistance, a low charging rate, and long time of charging. A modified, constant-potential system provides a means of selecting such a charging time as is available and satisfactory, and choosing the proper line voltage and ballast resistance.

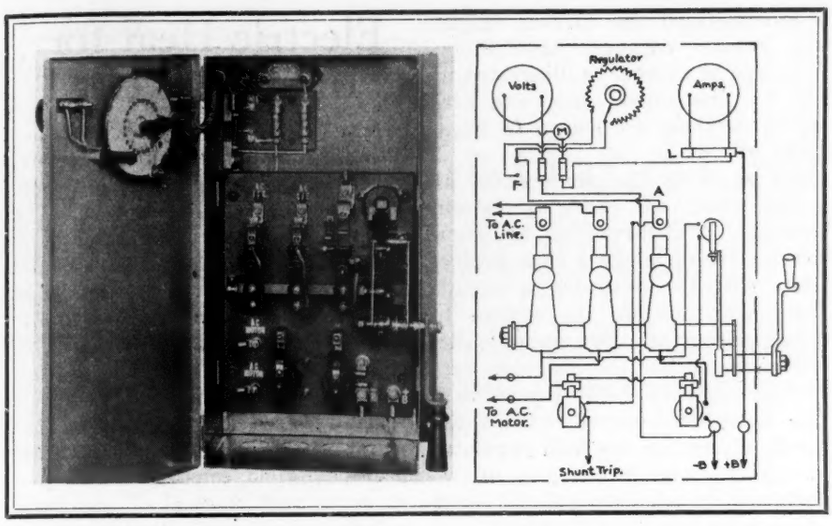
Under average conditions a charging voltage of 2.6 volts per cell is quite satisfactory for any lead battery and the manufacturers have worked out a table of ballast resistance values to be used to obtain the proper finishing rate for various types and sizes of cells.

With the alkaline battery, as was stated, there is no real constant-potential charging, for ballast resistance must always be used. One plan recommended by the Edison Storage Battery Company is to use a variable resistance that is hand operated, being adjusted from time to time so as to keep the current rate substantially constant.

Using the modified, constant-potential system the Edison Storage Battery Company recommends starting the charge at about 166 per cent of normal and finishing at about 66 per cent of normal, making the starting current about 2½ times the finishing current. It must be remembered, however, that this same ratio is not to be followed regardless of

Fig. 7—It is now standard practice to mount an ampere-hour meter on each industrial truck.

This meter shows the amount of charge remaining in the battery, also, while the battery is on charge, it shows the amount of charging yet required and automatically shuts down the charging equipment when the battery is fully charged. This illustration shows a Sangamo ampere-hour meter mounted on a Mercury tractor.



Figs. 8 and 9—Automatic control panel for a single unit charger. Fig. 8 shows the interior of the panel illustrated in Fig. 1, while Fig. 9 shows the connection diagram when looking at the panel from the front. The three large contactors in the center are operated from the handle on the outside of cabinet. The right-hand contactor *A* in Fig. 9 connects the battery to the generator and starts the motor-generator set. The two left-hand contactors are then closed, thereby connecting the motor to the line after which, charging of the battery begins. The rheostat at the top regulates the generator field current, which in turn controls the charging current. Two relays are shown at the bottom of the panel, the one on the right is an overload relay, while the one on the left operates in conjunction with the trip circuit from the ampere-hour meter on the truck.

absolute values. In other words, the battery should not be charged at a rate beginning with, say, the normal discharge rate and finishing at 40 per cent of this rate, as such a finish is too low for the best performance.

The Edison battery when fully charged requires a charging potential of about 1.84 volts per cell. The recommendation of the manufacturer is to insert an amount of ballast resistance per cell, dependent on the size of the cell, which will give a drop of 0.10 volt per cell or a total charging voltage per cell of 1.94 volts with 66 per cent of the normal current flowing. Hence, with 21 cells in a battery, the line voltage for charging should be about 41 volts.

With either type of battery and under practically all conditions it will be found that unless feeder, switch, and other resistance drops are in some way recognized, the current will always be less than supposed.

There are many places where direct current is not available; also, it is usually wasteful to use it because in most cases the number of cells under charge is so small that the charging voltage uses only a small part of the potential available and the larger part of the energy is lost. Hence, it becomes more and more apparent that a motor-generator set or, in the case of direct-current service, a dynamotor, affords an economical method of converting the service to the proper charging voltage.

Equipment large enough to carry all the batteries to be charged at one time should be provided. The equipment should be arranged so that each battery will have a ballast resistance, a circuit breaker and, if the charging is to be automatic, an ampere-hour meter or its equivalent. In addition to this, it is customary to add a voltmeter and ammeter so arranged that all necessary readings may be made on each battery as the charge progresses, as well as an additional ammeter to read the total current delivered by the generator. Circuit breakers with the usual features of overload protection are usually provided, and the motor is started through a compensator with overload and no-voltage release.

When it is desired to make the charging system automatic, an ampere-hour meter affords a very reliable means of terminating the charge. In this connection, the circuit breaker should be provided with a shunt-trip attachment having auxiliary contacts to open the tripping circuit and thus avoid arcing in the ampere-hour meter contacts. It is best to have each truck equipped with an ampere-hour meter, for with this arrangement the meter shows while on discharge how much energy has been taken out and permits the operator to judge about how much is still remaining. When the battery is again put on charge the current will cause the hand of the meter to gradually swing back to zero, which is the full position. On arriving at this point a contact is made which trips the circuit breaker and thereby stops the charging operation. The meter is so arranged internally that more energy is required to bring the hand back to zero or the charged position than it took to bring it to the point of discharge; in this way it takes care of the fact that more energy must be put into a battery than can be gotten out of it. An installation of a Sangamo ampere-hour meter on an industrial truck is shown in Figs. 4 and 7.

Charging equipment can be obtained for charging each battery separately, or the equipment can be arranged with multiple circuits for charging more than one battery at a time. Several advantages and disadvantages are incidental to the use of a multiple-circuit plant. A unit of this kind is compact and is usually somewhat cheaper in first cost than if a number of smaller, single-circuit sets were used. On the other hand, such a unit is generally only partly loaded so that its efficiency is not at its best. It dissipates considerable power in ballast resistance, which again means loss and inefficiency. It is generally more expensive to install on account of the more intricate switchboard and wiring, and in addition it provides no safety factor; that is, if the unit is out of commission the charging current must be secured elsewhere, if the trucking and hauling service is to be continued.

By dividing the charging capacity required into smaller units, each capable of serving one or two batteries at a time, some very decided advantages can be obtained. These small units will run on a fairly good load factor, use no ballast resistance and are thus more efficient electrically. They make a more flexible unit in that if a part of the trucking equipment is to be used at a distant part of the plant it is possible and generally advisable to move the necessary capacity of charging equipment to a point convenient to the temporary location of the trucks. There is likewise no possibility of the trucking service being suspended, for one unit down out of a number will not seriously cripple the charging service.

It might be added that with a number of smaller units, repairs will be made more promptly and more thoroughly, for this will remove the temptation of permitting the equipment to run on a temporary repair.

As against the installation of a single charging unit on the one hand and the use of small units on the other, there is the possibility of having two units both of which can be thrown in parallel, using a common switchboard and one set of buses. This obviates the danger of complete breakdown, but does not materially improve the efficiency for it does not eliminate the need of ballast resistors, nor does it improve the flexibility of the system, as the two units cannot well be separated.

The third alternative already referred to, is to install either dual or single plants so that at most only two batteries can be charged at one time from any one of them. Such machines can be arranged to be started from the battery and by means of a Sangamo ampere-hour meter or other device will shut down automatically when the battery is fully charged. Such units have the further advantage of being designed to take care of the particular type of battery, whether lead or alkaline, for which they are intended. A single unit charger in use on an Edison battery is shown in Fig. 1. A dual unit charger is shown charging an Exide lead battery in Fig. 4.

In Fig. 2 are shown the performance curves of a single unit charger for a lead battery. Note that the charge starts at a fairly rapid rate and tapers as it proceeds, to a safe finish. The time of charging is based on an 8-hr. period.

Fig. 3 shows the performance curves of a dual charger for lead batteries. Here *B* and *B-1* are the ampere and ampere-hour curves, respectively, with two batteries on charge. Should one battery become charged ahead of the other, which often happens because of only partial discharge, this battery is automatically disconnected and the plant readjusts its current to the rate required for the remaining battery, as shown in curves *A* and *A-1*. A view of the charger just described is shown in Fig. 4.

In Fig. 5 are shown the performance curves of a single-circuit unit designed for charging Edison batteries. Note the uniformity of the current after the first 2-hr. period. The initial drop is due to the warming up of the generator; after this is accomplished the current output will remain constant indefinitely. This type of charger is illustrated in Fig. 1. The control panel and wiring connections are shown in Figs. 8 and 9.

Fig. 6 shows the performance of a dual plant for charging Edison batteries. The curves that are numbered *1* are of amperes and ampere-hours with two batteries in circuit. The completion of the charge to either battery and its automatic disconnection, drops the charging rate for the remaining battery to curve *2*. The dotted-line curves indicate the result of setting the field regulator to accommodate the charging of two batteries of unequal capacity, such as an A-4 and an A-8 battery.

The entire capacity of the unit can be used to boost a single battery at the full plant capacity, if desired.

Automatic features can be provided to suit conditions. As a rule automatic cutting off of each battery when filled is called for, as well as shutting down of the plant as soon as charging is finished. Besides this, overload protection is generally demanded. As these units are started from the storage battery that is about to be charged no compensator is required and no line disturbance is created at the time of starting. This type of control and the connection scheme for it is illustrated in Figs. 8 and 9.

As to protection of the outfit in cases of line failure, there are several means of taking care of such an emergency. If the failure is of short duration it is generally advisable to permit the unit to float on the battery. This is, of course, impossible in the case of a large, multi-pole generator where the no-load current necessary to keep running is a serious drain on the battery and where the flat compound winding of the generator is likely to cause reversal of polarity and a consequent runaway of the machine. On a small unit this plan is very successful.

A second plan is to open the direct-current circuit by means of a reclosing breaker allowing the generator to come to rest. On resumption of service the motor will start, which on a small unit can be safely done without a starter.

A third plan involves the operation of automatically restarting the motor of a unit which has completely disconnected itself on line failure. After automatically restarting, the direct-current circuit closes as soon as the generator voltage is correct.

Electric Heat for Industrial Use

(Continued from page 159)

lining stands up well under the comparatively moderate temperatures to which this material is exposed. The electric furnace shown in Fig. 7 was installed in August, 1919, and has been in operation continually at temperatures from 1,400 deg. to 1,650 deg. F. since that date. The service is the heat treatment of steel in a tool and die shop. The original resistors are still in use and the maintenance cost of this furnace has been negligible, consisting mainly of an occasional renewal of the brick hearth which gradually wears out due to the sliding of charges of material on its surface. Metal hearths —a nickel-chromium alloy—are now generally used in furnace construction in place of the brick hearth.

The cost of the services of operators for plants using electric heat are always favorable. Good working conditions are desirable. Surroundings which promote the well being of the workmen are recognized as an economy in their promotion of both efficiency and contentment. The cleanliness of the heat process can be readily seen from Fig. 2. The confirming comments of operators on these points as regards electric heat are of interest and well worth considering.

The testimony of many users of electric current for heat treatment processes is that because of the uniformity of this method of heating there are but few defective pieces in the output of the heat treating plant and that this alone often justifies the choice of the electrical method of heating. A rejected part represents a loss of labor often a loss of material and a loss of service or profit from the sale of the part. As an incidental factor it is found that this uniformity of output materially reduces the time and cost of inspection.

The quality of the work produced in a heating chamber depends upon the quality of the charge of material, the skill of the operator and upon even heating and close control of the temperature of the work. Assuming the first and providing the last named heating chamber conditions, the entire attention of the operator can be given to the object of his efforts and both rate of production and quality of product are benefitted thereby.

Things that may happen when

Changing Right-Hand Coil Windings to Left-Hand

together with details of windings made by machine and by hand, and ways to correct reversed direction of rotation and other difficulties

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TO TELL when right-hand or left-hand coils are used, face the commutator end of the armature and inspect the coils above the shaft. If the starting and bottom leads of a loop winding, or the finishing leads of those windings having the wire cut at the end of each coil, are at your right, then the coil is right-hand. If the leads as above mentioned are at your left, the coil is left-hand. Right-hand coils are shown in Fig 1*A* and left-hand coils in Fig. 2*A*.

WITHOUT considerable experience in rewinding small motors, it is not always clear just what happens when a right-hand coil winding is changed to a left-hand coil winding, in the case of direct-current and universal-type motors used in small drills, vacuum cleaners and the like. In what follows the essential details of these windings will be explained, with the conditions that result in changes in the direction of rotation. The effects of reversed rotation on the fields of straight series machines and on the fields of universal motors with a non-compensating winding and with a compensating winding will also be explained, with instructions on how to correct the armature or field circuit so as to secure normal operation.

Before going into winding details, a definition of a "right-" and "left-" hand coil will be given. Consider an armature lying on a flat surface represented by the line *XX* in Fig. 1*A*, with the commutator end of the armature facing the observer and the coil above the shaft or above the line *YY*. Then if the starting and bottom leads for a loop winding or the finishing lead of windings having the wire cut at the end of each coil are on the right-hand side of the observer, the coil is "right-hand." If the leads as above are on the left-hand side of the observer, the coil is "left-hand." The winding shown in Fig. 1*A* has right-hand coils, while the winding in Fig. 2*A* has left-hand coils.

All loop windings put on with the Chapman winding machines have right-hand coils, and wind the coils across the core ends on the inside of the left-hand side of the shaft.

In Fig. 3*A* an armature is shown clamped in the winding jaws of a Chapman winding machine ready to start the first coil. It will be noticed that the armature is turned so that the commutator end is toward the operator, and that the starting lead is brought across the core end to the upper slot. In Fig. 3*B* the first coil is shown wound on the left-hand side of the shaft. Note where and how the starting lead is brought out from the first coil. By turning Fig. 3*B* clockwise 90 deg. we will have a perfect illustration of the definition given above for a right-hand coil.

In Fig. 3*C* the wire has been pulled up and looped over the snubbing pin ready to start the second coil. Note that in Fig. 3*C* the armature has been rotated counter-clockwise to bring the slots for the second coil into proper position. The finish of the second coil is shown in Fig 3*D* with the leads removed from the snubbing pin. This is the condition of the winding shown in the sketches of Figs. 1*A* and 1*B*. In Fig. 1*A* the two coils in place have the four leads marked S_1, F_1, S_2, and F_2. When the coils are laid out flat and the leads brought over to the commutator bars, as in Fig. 1*B*, this shows them to be "right-hand." The full-line arrows in Figs. 1 and 2 indicate the direction of rotation of the winding machine, while the dotted-line arrow shows the direction the armature is rotated in the holder to wind each consecutive coil in its proper order and position.

In Fig. 4 a 12-slot, 12-coil, and 12-bar loop winding is shown with the brushes on the center line of the neutral region. Right-hand coils are wound as shown in Figs. 1 to 3*D* and the leads brought out straight.

In this diagram, Fig. 4, the direction of current flow in the slots is shown by the arrows. The coils marked (*) are short-circuited by the brushes; hence no current flow is shown. In slots *8, 9, 10, 11, 12* and *1* the arrows point away from the center, while in slots *2, 3, 4, 5, 6* and *7* the arrows point towards the center.

With most home-made winding stands and all stands constructed to hold the armature by clamping the shaft and rotated by the left hand, the coils are wound across the outside or right-hand side of the shaft, as shown in Fig. 2*A*. That diagram also shows where and how the starting and finishing leads are located.

By turning the sketch of Fig. 2*A* so that the armature rests on the line *XX*, Fig. 2*B* shows the leads on the left-hand side; hence the coils are "left-hand." In Fig. 2*C* the armature has been rotated counter-clockwise 180 deg., bringing the coils on the inside of the shaft and the leads down or to the left, as shown in Fig. 2*D*. From Figs. 2*A*, *B*, *C*, and *D* it is obvious that by changing the winding from inside the shaft to outside the shaft, or *vice versa*, and with the starting and finishing leads both brought out together, that is, straight out, the coils are changed from "right-hand" to "left-hand" or *vice versa*.

With lap windings in which the leads are brought out in slots one coil pitch apart and the bottom and top leads brought over to commutator bars on the center line of the coil, changing from "right-hand" to "left-hand" coils or *vice versa* will not affect the direction of rotation as will be shown later. On the other

hand in lap windings with the leads brought out straight, as in Figs. 1 to 4, changing from one side to the other of the shaft or changing from "right-" to "left-hand" coils or *vice versa* does reverse the direction of rotation, as will be seen by comparing Figs. 4 and 5. Fig. 5 is the same as Fig. 4 except that the coils are left-hand and the lead throw is to the left. In Fig. 4 the coils are right-hand and the lead throw is to the right.

The slots and bars in Fig. 5 are marked the same as in Fig. 4 and the brush polarity is the same. By comparing the direction of current flow in the slots of Fig. 5, we find that in slots *1, 2, 3, 4, 5,* and *6* the arrows point away from the center and in slots *7, 8, 9, 10, 11,* and *12* the arrows point towards the center. This is just the opposite to Fig. 4, which with the same polarity of the field coils would result in the armature running in the opposite direction. The above shows that changing from left- to right-hand coils or *vice versa,* with the leads connected straight out, will result in reversed armature rotation.

Next, consider the case of lap windings, hand or machine wound, with the leads on the center line of the coil. A study of Figs. 6 and 7, which show right-hand and left-hand coil windings, will prove that changing from right- to left-hand coils or *vice versa* does not affect the direction of rotation. First consider Fig. 6. In slots *2, 3, 4, 5, 6, 7* the arrows point out and in slots *8, 9, 10, 11, 12,* and *1* the arrows point in. Next refer to Fig. 7, which has left-hand coils. In slots *1, 2, 3, 4, 5,* and *6* the arrows point out and in slots *7, 8, 9, 10, 11,* and *12* they point in. The only change is in slots *1* and *7* which are not in an active field; hence the direction of rotation is not affected.

The next step is to consider the effect of reversed rotation on the fields. In the small straight, direct-current, series-type, two-pole motors, we have two methods of connecting the field coils and armature in series with the line. One method is to connect one field coil lead to the line and the other lead to the brush. This puts the armature between the two coils, as shown in Fig. 8*A*. The advantage of this method is that flexible two-conductor cable for line leads can be connected to the field on the opposite side to the brush-holders.

The second method is to make a permanent connection between the two field coils before they are assembled in the frame. One line lead connects to one end of the field; the other field lead connects to one brush-holder, and the other line lead connects to the remaining brush-holder as in Fig. 9*A*. The advantage of this is that when a switch is incorporated in the motor for starting and stopping, the lead *a* from the brush can be permanently connected to one side of the switch and one leg of the line lead or portable cord connected to the other side of the switch.

In Fig. 8*A* the conditions are normal and the arrangement of the coils, armature connections, and current flow will be considered standard for clockwise armature rotation, which is indicated by the curved arrow. The arrow inside the armature circle indicates the direction of current flow from brush to brush, but it does not indicate the direction of current flow in the armature conductors under each pole.

In Fig. 8*B* we have the condition that exists when the coils are changed from right- to left-hand or

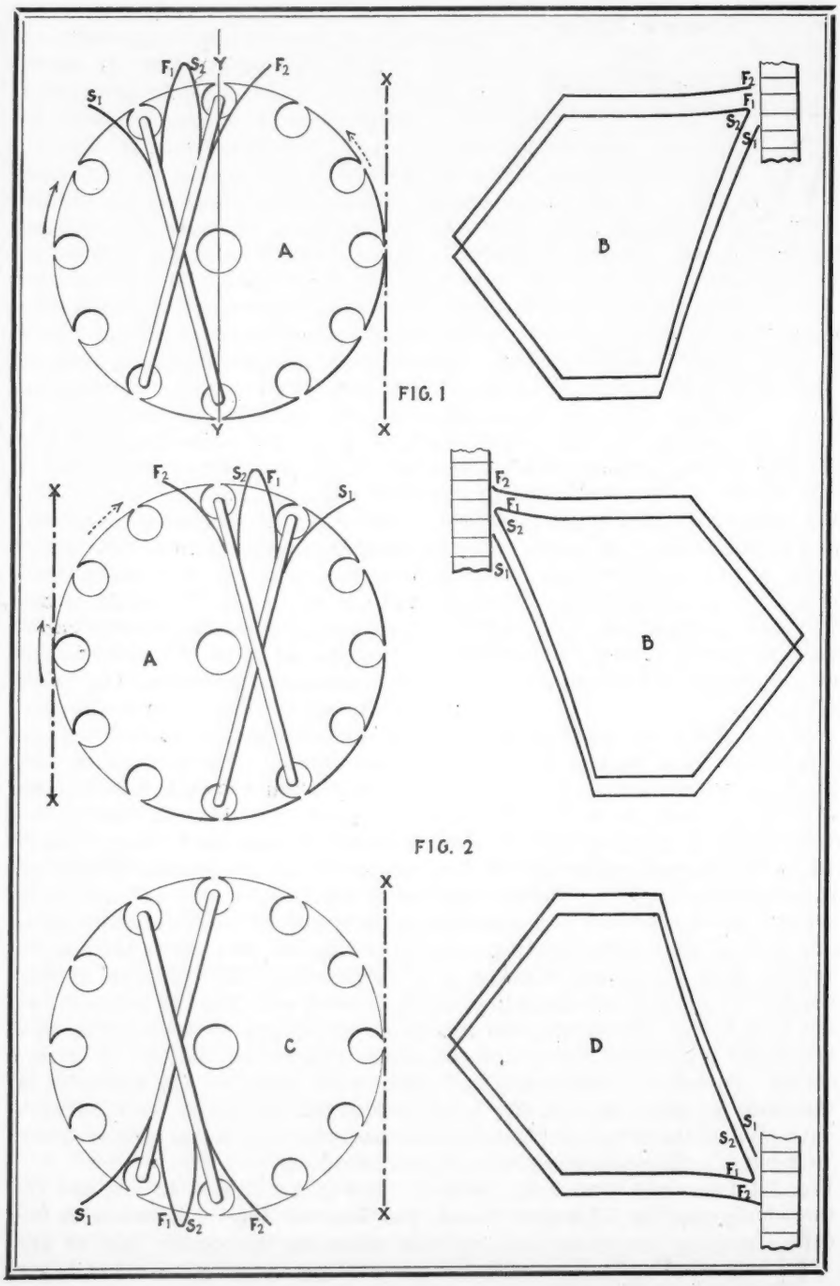


Fig. 1—This is a standard, machine-wound, loop winding on the left-hand side of the shaft, resulting in right-hand coils. This winding is shown again in Fig. 3D.

Fig. 2—Machine winding on right-hand side of shaft, resulting in left-hand coils.

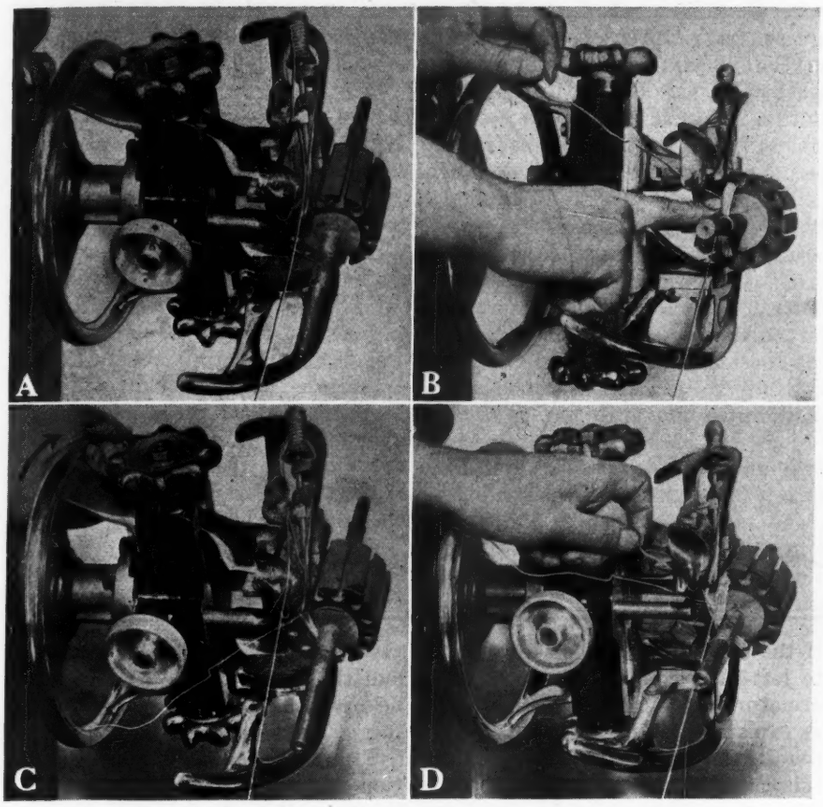


Fig. 3—Four stages in making loop winding with right-hand coils on Chapman winding machine.

A, armature clamped in jaws of machine, ready to start the first coil. *B* shows the first coil of the winding in place. Note how the starting lead is brought out. In *C* the wire has been pulled up and looped over the snubbing pin ready to start the second coil. *D* shows the finish of the second coil and a loop formed by the finish (F_1) of coil *1* and the start (S_2) of the second coil.

vice versa, with leads brought out straight. The current flow through the fields is the same; also the polarity of the brushes remains the same, but the current flow in the armature conductors under the poles has been reversed, as was shown in Figs. 4 and 5. This results in the rotation being reversed, as indicated by the curved arrow in Fig. 8*B*.

With a straight series motor if the reversed rotation can be used, no changes need be made in the field circuit. But if it is necessary to return the rotation back to normal, it can be done by interchanging the field coil leads connected to the brush-holders, as shown in Fig. 8*C*.

Fig. 4—Lap winding with right-hand coils and leads brought out straight at the right. Brushes are on the center line of the neutral region.

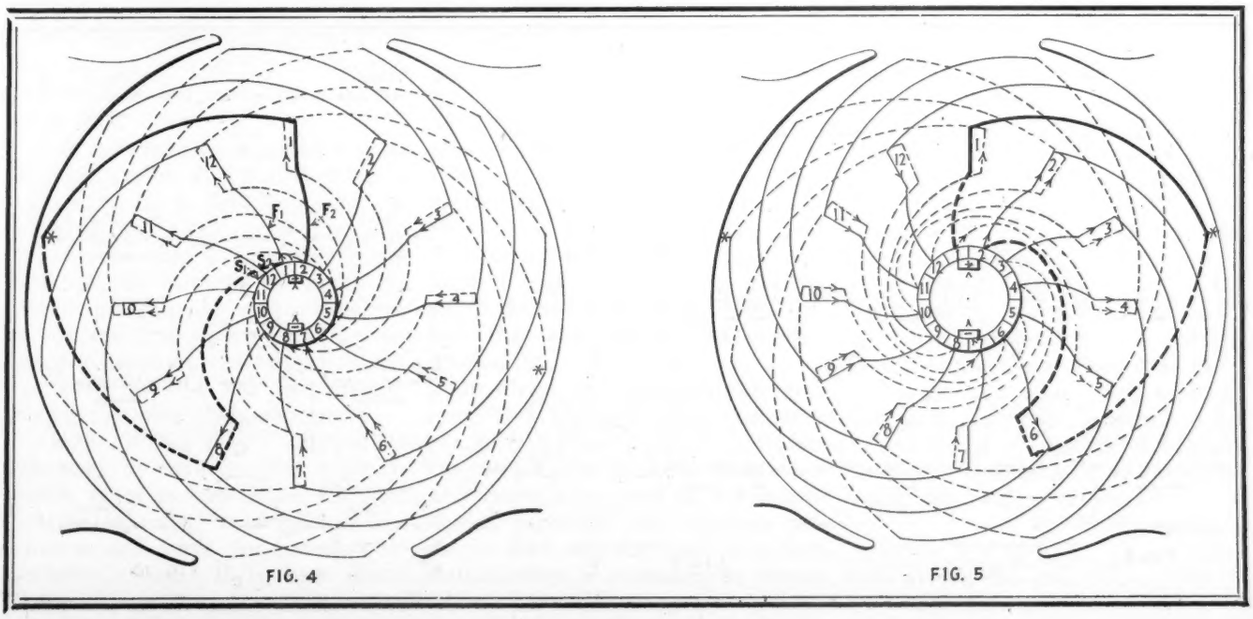
Fig. 5—Lap winding with left-hand coils and leads brought out straight at the left. Brushes are on the center line of the neutral region.

This changes the brush polarity and reverses the current flow through the armature, which changes the current flow in the armature conductors under the poles back to normal, and the rotation will be corrected.

The above method is the simplest for this type of motor, as in most cases the leads are attached to the brush-holders by spring clips or screws; hence it is not necessary to unsolder and resolder any joints. The mechanical arrangement of the leads and the space for them will depend upon the make of the motor.

The second method of making permanent connections between two field coils is shown in Fig. 9*A* which indicates conditions for normal operation. Fig. 9*B* indicates the conditions when the current flow in the armature conductors under the poles has been reversed by changing the armature winding from right- to left-hand coils or *vice versa*, with the leads brought out straight.

If the motor can be used with the changed rotation, it will not be necessary to make any changes either in the armature or field circuit. But, if the rotation must be changed to normal, the armature leads will have to be interchanged



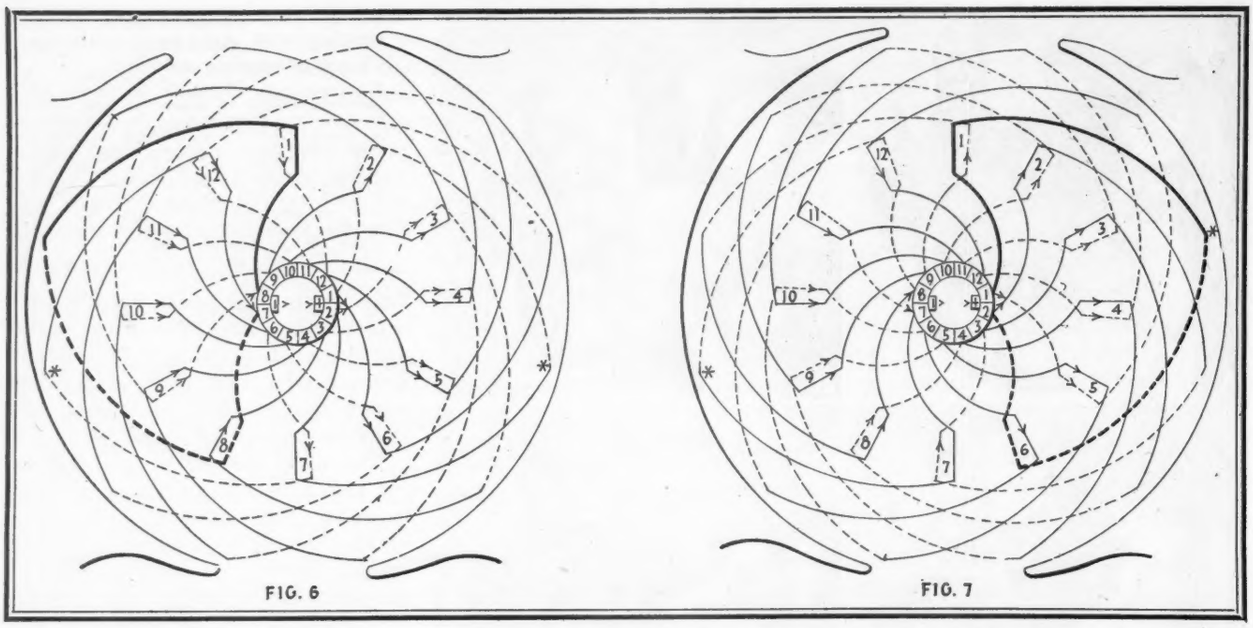


Fig. 6—Lap winding with right-hand coils and leads on the center line of coils. Brushes are on the center line of the poles.

Fig. 7—Lap winding with left-hand coils and leads on the center line of the coils. Brushes are on the center line of the poles.

as shown in Fig. 9*C*. This will change the brush polarity and return conditions to normal.

We now come to the compensated type of universal series motors. The usual procedure in these motors is to connect the compensating winding on one side of the armature and the main field on the other side, as shown in Fig. 10*A*, which also indicates normal running conditions. Now with armatures in which the coil leads are brought straight out, if the coils are changed from right- to left-hand coils or *vice versa* the armature rotation will be reversed, as explained for Figs. 4 and 5. This condition is shown in Fig. 10*B*. In this case the motor will not operate without sparking and heating and will not deliver its rated horsepower unless either the polarity of the compensating winding is changed or the polarity of the brushes reversed.

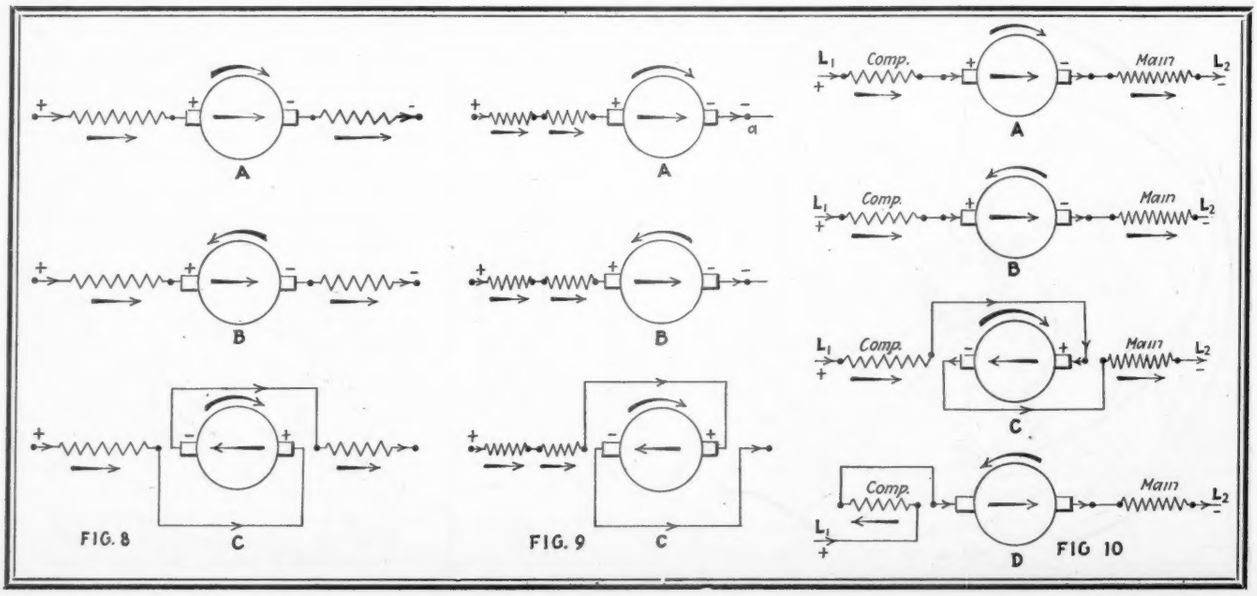
The reason for this is that the compensating winding acts against the armature reaction and it must have a fixed polarity with reference to the main field polarity and armature rotation. When the rotation is reversed the polarity of the compensating field must also be reversed, or if the current flow in the armature conductors under the poles is reversed, the rotation is reversed and the action of the compensating field is nullified, which causes sparking at all speeds and loads.

Fig. 10*C* shows how normal rotation and operation are secured by reversing the polarity of the brushes. This is done by interchanging the armature connections. The current flow through the main and com-

Fig. 8—Method of connecting one field coil lead to the line and the other to a brush in a two-pole, series motor.

Fig. 9—Method of making permanent connection between two field coils before being assembled in the motor frame.

Fig. 10—Connections for main and compensating field windings of compensated universal series motors.



pensating field coils is in the same direction, but the current flow through the armature has been reversed; thus rotation is changed back to normal.

If the reversed rotation of the motor is satisfactory for the application, normal commutation can be secured by interchanging the leads of the compensating field coils, as shown in Fig. 10*D*. This changes the polarity of the compensating field and corrects the relation between it and the armature rotation, and also the main field polarity.

On the smaller sizes of universal-type motors, that is, below ¼ hp., the main field winding is distributed in a number of slots per pole and to obtain a compensating effect the brushes are set permanently off neutral in the direction of rotation. It is obvious, then, that with this type of winding, when the armature rotation is reversed the brushes must be shifted to the opposite side of the neutral line, to an angle equal to the original offset. If the brushes are not shifted, sparking and heating will result. On the other hand, the polarity of the main field or brushes can be reversed, which will return the rotation to normal and eliminate the necessity of shifting the brush rigging.

The above points should be given consideration before changing from right- to left-hand coils or *vice versa* on armatures that have the brushes on the neutral line or shifted off neutral. In these cases the leads are connected out straight or given a throw in the direction of rotation of the armature.

Before making changes the field and brush-holder construction should be studied to determine what effect the change will have on the motor's operation and also how much trouble will be experienced in correcting the effects resulting from reversed armature rotation.

Comments on "Development and Use of Commutator Stones"

I WAS very much interested in the excellent article, "Development and Use of Commutator Stones," reported by Practical Pete in the March issue from a conversation with William L. Weber.

It has been my experience that there is no necessity of having a commutator stone made to fit the approximate curvature of the commutator. An artificial commutator stone will fit itself rapidly to the surface of the commutator and during the wearing-in process every revolution of the commutator changes the face enough so that the stone does not hit the flat spot twice in the same way.

It is true that a commutator stone will cut faster and better after it has worn to a full face, but in ordering the stone with the face already concaved the purchaser has just lost the value of the stone removed in concaving, and I have yet to see the first case where a commutator stone of the proper length has ever made a flat spot deeper during the wearing-in process.

As Mr. Weber points out, it is necessary to have a stone approximately twice as long as the flat spot is wide in order to completely remove it and leave the commutator perfectly round. It is very interesting to occasionally shut down a machine during grinding and note how the flat spot gradually narrows in width, but see how the center of the spot remains just as black as it was originally, showing that it has not been touched.

Just as soon as no blackness remains the grinding is done and not a thousandth of an inch more copper than necessary has been removed—less than the most careful workman can generally do with a turning tool.

Mr. Weber also touched on the glaze on commutators and slip rings. So far as I know there is never any advantage to a glazed surface on a slip ring and it is true that the removal of the glaze from a ring speeds up the acceleration of a slip-ring motor and may cut down the starting time as much as 30 per cent. This is quite important on a.c. elevator motors or other slip-ring motors that are started and stopped frequently.

On direct-current machines, however, this glaze is often necessary for good commutation. It increases the contact drop between the brushes and commutator and in many machines, especially non-interpole machines with varying load, this high contact drop is necessary to reduce the short-circuit currents in the coils undergoing commutation.

E. H. MARTINDALE.
General Manager,
The Martindale Electric Co.,
Cleveland, Ohio.

* * * *

I was much interested in the interview between Practical Pete and W. L. Weber published in the March issue, regarding the uses of commutator stones, and would like to add my views on the subject in the hope that they may benefit others.

I have been using stones of various makes for the past nine years with good results, and by their use considerable time has been saved which otherwise would have been lost in removing the armatures also undercuts the commutator.

The method I use is to start the cutting with a coarse stone, placing it in position on the brush rigging, with the commutator revolving toward the stone, and gradually cut the commutator by letting it swipe the stone until it is even or true. A fine stone is then used to smooth the suface, after which the surface is lightly polished with a sheet of very fine sandpaper. The latter gives the commutator a very high polish and removes all fine burrs. The next procedure, as soon as the machine can be conveniently taken out of service, is to bevel the edges of the bars with a slotting file; this undercuts the commutator at the same time.

For a beginner, a great deal of care is required in truing commutators with stones; otherwise both stone and commutator may be ruined. For instance, if continuous pressure is put on the stone while pressing against an elliptical commutator, the fault, instead of being remedied, is aggravated. It is, therefore, necessary that the stone be used in the same manner as the tool of a lathe is used.

I have also found from experience that too much pressure on the stone is not good, since if the machine being cut is loaded, either motor or generator, considerable flashing at the brushes will result. The brushes will also wear down very quickly. Even when using a high-grade stone, the brushes in some cases, as on an emergency job, have become red hot at the point of contact and blackened the commutator while undergoing the cutting process.

H. E. STAFFORD.
Electrical Engineer,
Provincial Paper Mills, Ltd.,
Port Arthur, Ont., Can.

INDUSTRIAL ENGINEER

Devoted to the Maintenance and Operation of Electrical and Associated Mechanical Systems in Mills and Factories

G. A. VAN BRUNT, *Managing Editor*

Can You Rely on Your Spare Parts in an Emergency?

ANYONE who has experienced the shock of learning that spare parts or supplies are unfit for use in time of emergency, does not have to be told that it is unpleasant, to say the least. The fact that spare parts such as armatures or rotors, coils, belts and the like are kept in stock for emergency service is ample proof that they are rightly considered to be very important.

However, when spare coils, for example, are found to be of the wrong size, or with the insulation rotted, or otherwise defective, there is plain evidence of carelessness on the part of somebody. So many things can happen to parts in stock that only careful storage and handling and frequent inspection will defeat some of the unsuspected enemies, such as rodents, dust, fumes, extreme changes of temperature, and so on, that cause stored material to deteriorate rapidly.

Then again, there is always the possibility of spare parts being ordered for the wrong type of machine, particularly when these have been purchased second-hand, or altered in any way.

A great deal of unnecessary trouble can be saved by taking care to store spare parts in a clean, dry place that is free from corrosive fumes, checking up and testing all material carefully before it is placed in stock, and inspecting it frequently thereafter. By so doing not only will the cost of wasted material be saved, but service delays and very costly and unpleasant situations will be avoided.

Will the Oil-Electric Locomotive Reduce Cost of Steel Mill Yard Switching?

IN VIEW of the recent developments in the oil-electric locomotive, this form of motive power should be of particular interest to industries having considerable yard switching such as is the case in the steel mills.

Recent tests made by the Central Railroad of New Jersey in one of its terminal yards resulted in an average fuel cost for the oil-electric locomotive of $1.16 per 1,000 tons of freight handled, while the fuel cost of a steam locomotive operating under the same conditions over an equal period of time was $6.92 per 1,000 tons of freight handled. Fuel costs are only one of the several economies that are expected to be obtained with the oil-electric locomotive. Use of it will eliminate coaling stations, ashpits, and turntables and is expected to do away with expensive round houses and hostling services. The maintenance cost of the oil-electric locomotive is said to be much below that of the steam locomotive; this means that in addition to the saving in money, due to decreased maintenance, the oil-electric locomotive will spend more time in service, and less in the round house.

For some time the steel mills have been very much interested in reducing their yard switching costs. Electric locomotives supplied from overhead trolleys have been proposed, but discarded as impractical, due to the necessity of having overhead space clear for yard jib cranes, traveling cranes, locomotive cranes, and the like. Third rail locomotives have been seriously considered, but due to the large number of tracks located in a congested area, the trackage and switching becomes very complicated. One steel plant, in the endeavor to reduce its yard switching costs, has installed a large, storage-battery locomotive. The outcome of this installation will be awaited with interest.

The oil-electric locomotive appears to be an ideal solution of the steel mill yard switching problem. It goes without saying that the test results of these locomotives obtained by the various railroads will be watched closely by steel mill operating engineers who are alive to possible cost reductions that may be thereby obtained.

Selecting the Best Method is an Important Part of Any Job

NEED, on the part of industrial operating executives, for quick thinking and ingenuity in meeting unusual conditions was brought out some time ago by an incident that is not without a humorous aspect.

In a certain plant a large water tank is mounted on a supporting structure above the main office. During severe cold weather one winter a huge icicle formed on the tank and when it eventually broke loose it crashed through the roof of the office, causing a good deal of damage.

The following year another icicle formed and had grown to dangerous size before it was noticed. The office employees refused to stay at their desks and in the absence of the Master Mechanic there was a hurried consultation to decide the best way of removing the icicle before it broke loose. The weather was extremely cold and no one wanted the job of climbing up and knocking the icicle down, as it was in reality a dangerous undertaking.

Before action was taken the Master Mechanic returned and took in the situation at once. He slipped out of the office and within a short time had solved the problem cheaply and simply by shattering the icicle with a rifle bullet. That may not always be the best way of getting rid of icicles, but in this instance it served the purpose well.

Speed in undertaking a job is oftentimes highly desirable, but the method that first comes to mind is not always the best one. In the long run, time can often be saved by studying the situation with sufficient care to make sure that the methods used are the simplest and most efficient, all things considered.

Be Sure That Your Money-Saving Ideas Will Really Save Money

NOT LONG ago we heard of a money-saving idea that wins the prize for misdirected effort towards economy in plant operation.

A well-known steel plant has a number of large motors and several turbo-generators, which are supplied with air that is passed through air washers for cooling and cleaning. It costs money to pump water at this plant and the management decided that a considerable saving could be made by shutting down these air washers during the winter months when cooling of the air was not required. This was done and a saving was made, but unfortunately this saving was lost the next summer, due to an insulation failure on one of the large motors. This failure was traced to dirt in the armature of the motor and the logical reason for dirt getting in there, was because the air washer did not have an opportunity to remove the dirt before it reached the motor. Rewinding of the armature was required—a job that was done very expeditiously in five days. Meanwhile the entire mill was shut down and the cost of this delay in production, added to the rewinding cost of several thousand dollars, swallowed up many, many times the small saving in water cost.

Air washers are installed primarily to clean the air and the fact that they cool the air at the same time is only a secondary consideration. Knowledge of, or consideration of, this simple fact would have saved a large amount of money and a great deal of trouble.

A careful investigation should be made of all angles of a money-saving idea before it is put into operation. There is a reason for the use of most plant equipment and elimination or shutting down of part of it should be done only after careful consideration of the possible consequences.

Improper Application of Equipment May Cost More Than You Realize

EVERY operating engineer knows from experience that it is not difficult to find many instances of failure to secure maximum output or service from some installation, due to faulty application of one or more component pieces of equipment. A case in point came to light recently in an industrial plant which makes use of a special and costly machine for performing certain operations on four different sizes of metal stock. Naturally, the operations on the heavier stock must be performed at slower speeds than in the case of the lighter stock.

Through ignorance or carelessness, when this machine was originally installed a constant-speed drive was selected. This meant that the machine speed had to be limited to the value that was suitable for handling the heaviest stock, whereas light stock was handled a large part of the time.

At length, someone who had a wider knowledge of the results that can be accomplished by proper selection of motor and control equipment, suggested that a variable-speed motor and suitable control be used on this machine. The change was made and production has increased considerably, as each weight of stock can now be handled at the maximum suitable speed.

In many cases the selection of the control equipment should receive more attention than it now gets. Control engineering has made so many advances during the past few years that it is safe to say that many engineers do not fully realize the results that can be accomplished, and the possibilities that are offered, by well-designed control equipment.

The next time you have occasion to select control equipment, investigate thoroughly the designs available and make friends with a few good engineer salesmen of this equipment. You may learn some things that will surprise you, and that you can use to good advantage.

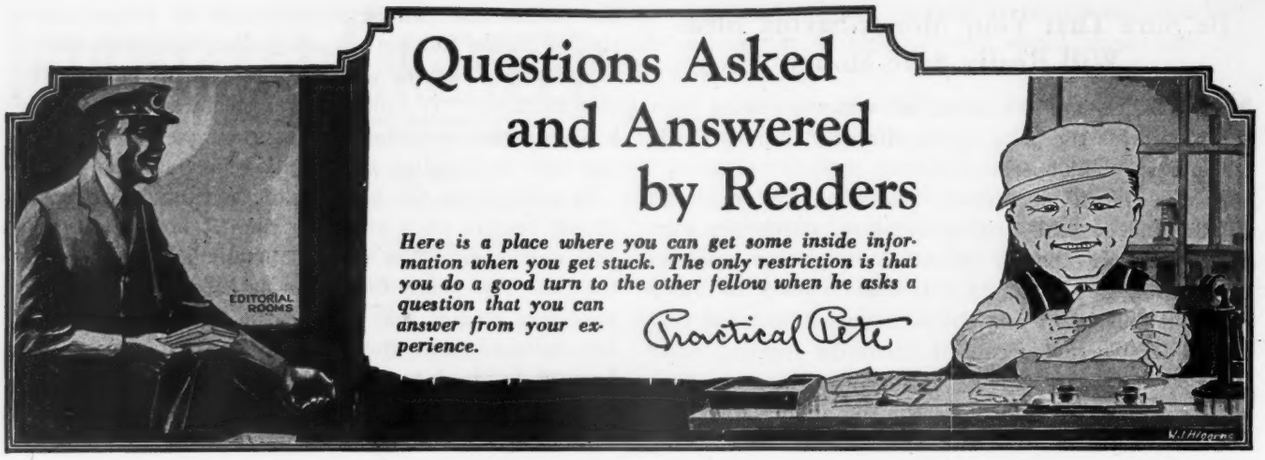
Take a Day Off and Visit Your Neighbor's Plant

THERE is nothing like the word-of-mouth method for passing on helpful experiences. One way of obtaining this contact is through association meetings or conventions; however, these meetings are too infrequent and quite often degenerate into good-fellow parties rather than into exchanges of experiences in solving operating problems.

Seemingly it is hard for some to realize that their neighbor's plant is confronted with problems very similar to their own. Of course, it is quite common to look over another man's plant when deciding upon what kind and type of new equipment should be obtained. But the visits should be made oftener and with the view of obtaining operating information and ideas as well as the foregoing. Also, visits should be made to a greater variety of industrial plants than would be true if new equipment only were to be inspected. If your neighbor manufactures the same product that you do, it is quite likely that he will look at his problems in the same manner that you do. On the other hand, the operating man in another kind of industry may attack the same problem from an entirely different angle.

The International Harvester Company is one organization that recognizes this fact, and encourages visits between men in its various plants. In fact, this company goes so far as to organize regular trips on which even the foremen from one plant will visit those of another. For example, those engaged in making tractors may visit a rolling mill; those that make trucks may visit the harvester plants, and so on.

After all, doing something better than it was done before is simply the fruition of an idea. Ideas do not come out of thin air; they come from experiences, things we have seen, and our imagination. Give these forces a chance to develop by talking things over with your neighbor during a visit at his plant. Both he and you will benefit thereby.



Questions Asked and Answered by Readers

Here is a place where you can get some inside information when you get stuck. The only restriction is that you do a good turn to the other fellow when he asks a question that you can answer from your experience.

Who Can Answer These?

Method of Checking Bearing Alignment.—I should like to know how to check the alignment of bearings on machines having three or more bearings supporting the same shaft, or where two shafts are coupled together by means of rigid couplings. An example of this is a three-bearing, motor-generator set or a large, heavy-duty motor or pump having a pedestal bearing in addition to two regular bearings. I shall appreciate any suggestions that readers can give me for doing this work.
Chicago, Ill. F. B.

* * * *

Can Slip Ring Motors Be Started by a Compensator?—I have several three-phase, 440-volt, wound-rotor, induction motors ranging in size from 25 to 150 hp. I have several spare compensators which I would like to use for emergency starting of these motors in case anything goes wrong with the present drum controller and secondary-resistance type of control. My plan is to short the slip rings and start the motors with a compensator just as though they were squirrel-cage induction motors. Is this practicable? Is there any danger of damaging the motors? I would like to know the experience of other readers in this regard.
Chicago, Ill. W. J. A.

* * * *

Where Should I Use This Kind of Wire?—Most manufacturers of wire for use in house wiring and in industrial plants make three kinds of wire: a Code wire, an intermediate grade and a 30 per cent rubber compound grade. I should like to learn from other readers whether they use all three grades around their plants and if so, the basis on which they decide the grade that shall be used for a certain application. Do you find any of these grades unsuited for industrial plant use? I shall appreciate any information that you can give me regarding the proper application of these three grades of wire.
Newark, N. J. B. S.

* * * *

Tests on Motors Do Not Check Nameplate Data—We have three 200-hp., 600 r.p.m., 60-cycle, three-phase, 440-volt, wound-rotor, induction motors, that are used to drive tube mills in our cement plant. According to the nameplate, the full-load, primary current is 245 amp., while the full-load secondary current is 346 amp. On making a test on one of the motors, I found that with the belt off the primary current was 125 amp. Upon putting the belt back on the pulley and loading the motor, the primary current rose to 275 amp., while the secondary current went up to 150 amp. Upon increasing the load, the primary current reached 350 amp. and the secondary current 275 amp. According to the nameplate the primary current should be less than the secondary current, while the tests show just the opposite. The temperature rise on the motors so far has stayed below 40 deg. Can some reader tell me what is the matter with these motors?
Ragland, Ala. R. I. F.

* * * *

Changing Speed of Induction Motor.—What will be the horsepower and power factor of a 3-hp., Fairbanks-Morse, 1,200-r.p.m., 6-pole, 54-slot, standard factory wound, 60-cycle, 440-volt induction motor, wound with No. 16 wire in 54 coils with 28 turns per coil, span 1-9, when this winding is regrouped for eight poles instead of six?
Portland, Ore. P. M. W.

* * * *

What is Function of Reactive Volt-Ampere Indicator?—We recently ordered from a meter manufacturer a three-phase, switchboard-type wattmeter. When the meter arrived at the plant it was marked, reactive volt-ampere indicator, instead of wattmeter. I wish some of the readers of this column would explain the difference between these two meters and tell me the application and use of the reactive volt-ampere meter. Any details regarding the use of this meter will be very helpful.
Detroit, Mich. R. J. B.

* * * *

Trouble in Keeping Commutator Bars Straight.—I have considerable trouble in keeping commutator bars true and straight when the commutator is put back on the shaft of the armature after being repaired. The type of armature that I have particular trouble with is a ½-hp., d.c., No. A3, Westinghouse motor. The commutator is held in place by the front and rear V-rings which are locked in place by means of a plate screwed onto the armature shaft. In tightening this plate the armature bars move at an angle or become skewed. Can some reader tell me how to assemble these small commutators in such manner as to prevent them from skewing?
New York, N. Y. B. L. A.

* * * *

What Causes Heating of This Cable Box?—There are six 1,000,000-circ. mil cables connected in parallel per phase on the cable run between our 2,000-kw. 3,000-amp., 480-volt turbo-generator and the oil switch. These cables are grouped in six conduits, each of which holds one cable from each phase, or a total of three cables. The conduits terminate in the bottom of a sheet-iron distribution box. In this box the cables are regrouped so that all of the cables from one phase go out of the left-hand side of the top of the box; all the cables for another phase go out through the center of the top of the box; and the six cables for the remaining phase go out through the right-hand side of the top of the box. With this arrangement the entire top half of the sheet-iron distribution box heats up. What causes this heating and how may it be overcome? Should I make the box of fiber instead of sheet iron.
Bellingham, Wash. E. M. D.

Answers Received To Questions Asked

What Is the Best Type of Drive for This Installation?—I should like to have the advice of readers on the following problem. We wish to operate by a 10-hp., 1,150-r.p.m. motor, a small machine shop and a small reciprocating pump, which are in different rooms, separated by an 8-in. brick wall. We wish to place the motor in the room with the pump. There are three possible drives. (1) Mount the motor on the floor or wall and use a short, overhead lineshaft with three pulleys, one for the motor belt, one for driving the pump and the other for driving the machine shop. (2) Mount the motor on the ceiling and connect it directly to a short lineshaft with two pulleys, one for the pump and one for the machine shop. (3) Mount the motor on the floor and drive the pump directly through a speed reducer. In this case I would use between the motor and the speed reducer a short piece of shaft on which would be mounted a pulley driving an overhead shaft, which in turn would be belted to the machine shop lineshaft. Will someone please tell me which of these combinations would be best from the standpoints of cost, maintenance and operating advantages? Do you know of a better type of drive than I have outlined?
Chicago, Ill. O. H. E.

In reply to the questions asked by O. H. E., I advise using method No. 1, with the motor suspended from the ceiling. This will allow a horizontal belt drive from the motor to the short lineshaft and will not require as tight a belt, as would be the case if the motor were mounted on the wall or floor.

It is not advisable to connect the motor directly to the pump shaft. In this case speed reducers would have to be used. These are expensive. Also, the use of flexible couplings should be avoided, if possible.
Watertown, Mass. F. B. WILLIAMS.

* * * *

The second drive as outlined by O. H. E. will be the best to use as it does away with some of the belting which would be necessary in the first case. The third method would be more expensive. Furthermore, connecting the shaft extension to a speed reducer and running a belt from it, is not, in my opinion, very good operating practice.

Two modifications of the second plan are suggested. When a motor is mounted on the ceiling there is not always enough headroom to permit con-

venient oiling and cleaning of the motor. A platform on which the motor might be mounted could be built and suspended from the ceiling. This method of installation would keep the motor and one belt away from the floor and out of the way.

Another plan would be to purchase a motor with a shaft extension on each end, and two pulleys. This would do away with the countershaft, as the pump and machine shop could be belted directly to the motor shaft. The motor could be mounted either on the ceiling or on a suspended platform, as suggested above. If a new motor is being purchased, one with a special shaft extension may be obtained in a few weeks time, at slight extra cost.

Boston, Mass. L. B. MORRILL.

* * * *

Replying to the question by O. H. E., the first type of drive he mentions appears to be the best from the standpoint of maintenance and construction. In view of the fact that motors are generally given very little attention on small installations, I would advise against placing them on the ceiling. Motors mounted in this position are very difficult to repair or clean. They are much easier to maintain if they are mounted on the floor or on wall platforms. In the latter case the wall platforms should be rigid enough to resist all vibration, and large enough for a man to stand on either side of the motor.

The floor is an excellent place to mount a motor, but usually floor space is limited, while plenty of wall space is usually available. On page 597 of the December issue O. H. E. will find a neat little motor stand which may be built cheaply in almost any shop. The only disadvantage is that the platform looks to be rather small and the oiler would have a difficult task in determining whether the bearings were well oiled, unless he carried a ladder with him to place on either side of the motor. It is not good practice to use portable ladders and they should be discarded and replaced with permanent ones, where required. Safety first always pays.

Chief Electrician, LEE F. DANN.
Donnacona Paper Co., Ltd.,
Donnacona, Que., Can.

* * * *

Referring to O. H. E.'s question, the first drive that he suggests is the best. Locating the motor on the floor or on a wall bracket and belting to a lineshaft and then to the pump and machine shop, will allow the installation to be made of standard material, that can be readily procured and replaced, at low cost in case a breakdown should occur.

The objection to the second alternative, mounting the motor on the ceiling and connecting it directly to the lineshaft, is primarily a question of the motor speed. The motor speed of 1,150 r.p.m. would be too fast for the ordinary lineshaft bearings and would probably give unsatisfactory pulley ratios for driving the pump and machine shop. In this case the lineshaft pulleys would be prohibitively small, or the driven pulleys unreasonably large. A less vital matter would be the relative inaccessibility of the motor for oiling, minor repairs, and other maintenance.

Using a speed reducer between the motor and pump shaft, as suggested under method No. 3, is objectionable because of the cost. Speed reducers are well built, but are more expensive, in comparison with ordinary lineshaft material. For satisfactory operation there should be flexible couplings on both sides of the speed reducer, between the motor and the pump, which would increase the cost of the power drive still further.

No. 1 type of drive will be the most satisfactory if the space available and the speed ratios will permit its use. A properly arranged drive using leather belts of ample width and thickness will be more efficient and cause less operating trouble than any other type of drive. If an accident occurs to any part of the driven machinery, about all that can happen is that the belt will slip off, without breaking chains, tearing teeth out of gears, or otherwise damaging the transmission machinery.

Plant Engineer, H. D. FISHER.
New Haven Pulp & Board Co.,
New Haven, Conn.

* * * *

Referring to O. H. E.'s problem, a little more information, such as the following questions suggest, would help in deciding which arrangement is the most efficient. Is the machine shop load constant? Is the shop operated intermittently or continuously when the pump is operating? Does the pump operate continuously or intermittently, and at what speed? Is the motor a.c. or d.c.? Are clutches to be used for disengaging units for no-load starting of the drive?

Arrangement No. 1 is the cheapest, most practical, and represents the most common practice. Clutches may be used on each side of the main drive pulley on the line or jackshaft to throw off the machine shop load as required, or in case of accident. The pump can similarly be thrown in or out of service as occasion demands, and the starting of the motor facilitated by disengaging the clutch.

Drive No. 2 has the disadvantage that the jackshaft speed would be too high, unless a special ball or roller bearing construction were used. Also aligning the motor with a shaft would require four bearings in line, which is objectionable unless a flexible coupling were used between the motor and jackshaft. Altogether, this arrangement is not very flexible and practical, considering individual operation and starting.

Drive No. 3 is the most expensive, as several flexible couplings would be required if the speed reducer were mounted between the motor and pump. This arrangement is not very flexible, and like arrangement No. 2 would require a higher grade of maintenance service.

Engineering Dept., E. H. LAABS.
Cutler-Hammer Mfg. Co.,
Milwaukee, Wis.

Is This Lamp Consumption Too High?—Our plant is a malleable iron foundry and our lights are operated from 230-volt direct-current power supply. During the first 314 days of this year, we used a total of 972 lamps in 847 outlets, making an average consumption of 1.33 lamps per outlet per year. To be specific, we used 230, 100-watt type C lamps in 275 outlets, or 0.97 lamps per outlet per year. We used 162, 200-watt type C lamps in 160 outlets, or 1.18 lamps per outlet per year. For portables and extensions at molders' benches we used 600, 50-watt, mill-type lamps in 412 outlets, or 1.7 lamps per outlet per year. The large lamps are subjected to slight vibration due to machinery and lineshafting. The lamps burn 9½ to 10 hr. per day. I should like to know whether other readers think that our average lamp consumption is too high. Also I shall appreciate any information regarding lamp consumption in plants having conditions similar to a foundry, as well as in other types of manufacturing plants.

Chicago, Ill. W. A. B.

Replying to W. A. B.'s question, the number of lamps required during daylight hours depends entirely on the amount of natural illumination available. If the windows are small or dirty more lamps will be required than would otherwise be the case. Natural illumination may be accurately measured with a foot-candle meter.

For a foundry the intensity of light in foot-candles should be as follows: On the charging, tumbling, cleaning, pouring and shaking-out floors, 2 to 4 foot-candles, where rough molding and core making are done, 3 to 6, and for fine molding and core making 5 to 10 foot-candles.

The lighting arrangement for a certain foundry approximately 80 ft. by 200 ft., or a total area of 17,600 sq. ft., is: 300-watt Mazda lamps in RLM standard dome reflectors, spaced 30 ft. by 40 ft. and hung 35 ft. above the floor. This hanging height permitted the use of bare lamps, but with an increased height the spacing could naturally be increased. The average intensity of illumination is 5 foot-candles.

These lamps are lighted only on dark days, in the first part of the morning or in late afternoon. They were not used between the hours of 10 a. m. and 2 p. m. more than five or six times last year.

Boston, Mass. F. B. WILLIAMS.

* * * *

In answer to W. A. B., I would say that he is to be congratulated, because foundry service is very hard on electric lamps. Owing to the accumulation of dirt, lamps have to be cleaned frequently, which increases the liability of breakage. Also, the use of portable lamps and extension cords tends to shorten the life of the lamps, which is likewise true to a less extent for fixtures subjected to vibration. Based on an average of 9.75 hr. per day for 314 days the lamps were burned 3,061 hr., which is a trifle over three times the rated life of the lamps.

According to the actual rated life of these lamps, the total consumption would have been 2,970 lamps in comparison to the 972 that were used. However, this comparison is too good to be true for the modern lamp, which is rated for 1,000 hr., but is considered all right to use until broken. After 1,500 hr. the output decreases to such

an extent that it produces only about 90 per cent of its rated lumens. Iron and steel plant applications are comparable to foundry lighting and in fact include it. In such a plant having 3,865 outlets, there have been as many as 12,300 lamps charged out in one year. This large consumption of lamps has been reduced recently by good management and improved lamp design.

If it were possible, it might be said that W. A. B. was not using enough lamps per year. Money invested in illumination produces a greater return than any other similar sum spent on plant equipment. A dollar now buys 16 times the illumination that it did 35 years ago. During the past decade the increased return on the investment has been about 62 per cent.

Electrical Engineer, D. W. BLAKESLEE.
Jones & Laughlin Steel Corp.,
Pittsburgh, Pa.

* * * *

Cleaning Wire-Mesh Carbon Brushes—What is the best way of cleaning wire-mesh, carbon brushes that are heavily coated with carbon dust and dirt? Scraping with a knife is slow and not entirely satisfactory. Is there some solution that could be used to clean them? These brushes are used on an old plating generator that is subjected to frequent overloads and the commutator is slightly grooved; so there is considerable sparking. The commutator has been turned down about as much as it can be and as the generator will be replaced before long we do not want to put on a new commutator. However, I must keep the generator in as good condition as possible until it is replaced.

Milwaukee, Wis. A. J. K.

In answer to the question asked by A. J. K., relative to the method of cleaning wire-mesh carbon brushes, I have found it very satisfactory to put the brushes in a copper plating solution and electroplate them until they look like new. The brushes are thus cleaned off while undergoing the plating in the plating bath. I have used this method quite a number of times and have found it entirely satisfactory.

Chief Electrician, HARRY J. ACHEE.
City of Woodward,
Woodward, Okla.

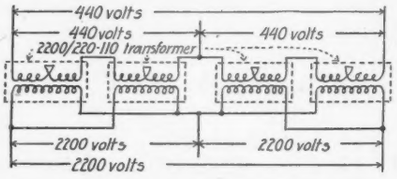
* * * *

I would suggest that A. J. K. use gasoline to scrub the brushes, with which he is having trouble. A steel bristle brush will clean the pores of the brushes especially near the surface. After the gasoline has dried off, soak them for about 30 min. in a solution composed of two parts of water to one part of ammonia. Then remove them from the solution and put them in clean water, rinsing them thoroughly. If this does not remove all of the grease, the solution can be made stronger. It is well to wear rubber gloves when handling the brushes in this ammonia solution, because the strong solution injures the hands to a certain extent, especially if there are cuts or bruises on one's hands.

I have also used sulphuric acid for cleaning copper brushes and this method could be easily used around a plating establishment, such as is the case with A. J. K. The proper way to proceed with this method is to first dip the brushes in a hot potash solution and then rinse them in clear water. The brushes may then be dipped in sulphuric acid until all grease is removed. There is a danger, however, in using this method in that the acid might not be entirely removed from the brushes and when the brushes are put on the commutator they might injure its insulation. Special pains should be taken to remove all of the acid from the brushes. GRADY H. EMERSON.
Birmingham, Ala.

* * * *

What Is the Capacity of this Transformer Bank?—I have four 25-kva., 2,200/220/110-volt transformers connected to a three-phase, 2,200-volt, power supply as is shown in the accompanying diagram. The secondary of each transformer is so connected that the two 110-volt windings are in series to supply 220 volts. As can be seen from the diagram, 440-volt, three-phase power is obtained from the secondary of this bank of



transformers. I shall greatly appreciate it if some reader will tell me what the capacity of this bank of transformers is with the connection that I am using. I should also like to know the safe secondary line current and also the safe primary line current that these transformers will take with this connection.

Hattiesburg, Miss. J. M. M.

Answering J. M. M.'s question, the connection he is using is open delta. The bank of four 25-kva. transformers operated on this connection has a capacity of 86.6 kva. The full-load, high-tension current at 2,200 volts is 22.75 amp. and the corresponding low-tension current at 440 volts is 113.7 amp. These values do not take into consideration the small losses that occur in the transformers, but are close enough for loading up the bank.

Morgan Hill, Calif. I. J. GRONWOLD.

* * * *

Referring to the query of J. M. M., concerning the connection of four 25-kva. transformers, I would say that the arrangement he shows is practically equivalent to an open-delta connection with the primaries two in parallel and the secondaries two in series. In other words, another set of two transformers similarly connected across the third phase would give a balanced delta connection.

The regulation and efficiency of the open-delta connection are poor, since one phase of the load receives power from two sets of two transformers in series.

It is customary to use the open-delta connection for installations that will grow, to save in first cost. When the load demand increases, the delta is closed by the addition of a third transformer, or set of transformers.

The total capacity of the transformers in an open-delta connection should be 15 per cent greater than the load. This means that the load on an open-delta connected bank of transformers should not exceed 87 per cent of their rating.

Since all coils are in use in the four transformers in this bank, the capacity available is 87 per cent of 100 kva. or 87 kva. Neglecting exciting current, the full-load primary current is equal to $(87 \times 1{,}000) \div (2{,}200 \times 1.73) = 23$ amp., and the full-load secondary current $= (87 \times 1{,}000) \div (440 \times 1.73) = 114$ amp. These calculations are based on the formula, Kva. $= (E \times I \times 1.73) \div 1{,}000$, and $I = (\text{kva.} \times 1{,}000) \div (E \times 1.73)$, in which E=volts, I=amperes, and kva.=kilovolt-amperes.

FREDERICK KRUG.
Supt. of Power Production,
Porto Rico R. R., Light and Power Co.,
San Juan, Porto Rico.

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In answer to the question asked by J. M. M. regarding the safe current loads in primary and secondary of a 100-kva. transformer bank, I would say that the connection scheme shown in the diagram is the familiar open-delta connection and is good for a load of approximately 58 per cent of the load that can be carried on a closed-delta connection employing the additional transformer or, in this case, two transformers. The kva. load capacity in the foregoing case is 87 kva. Safe primary current at 2,200 volts will be 22.5 amp. and safe secondary current 113.5 amp. If he has any facilities for cooling the transformers, such as a cold air draft or cold water sprayed on the cases, the load can safely be increased 25 or 30 per cent provided the oil is in good condition.

Chief Electrician, LEE F. DANN.
Donnacona Paper Co., Ltd.,
Donnacona, Que., Can.

* * * *

In reply to J. M. M., I would say that his diagram shows a bank of transformers with both primary and secondary sides connected open delta or V. The capacity of this bank will be approximately 87 kva., as may be seen from the following analysis.

Let I=the maximum phase current; then the corresponding line current with a delta connection will be equal to $1.73 \times I$. However, with an open-delta connection the line current will be equal to I; that is, the line current will equal the phase current. Therefore, the output of an open-delta connection as compared to a closed-delta connection will be in the ratio of I to $1.73 \times I$ or 1 to 1.73. In other words the capacity of an open-delta connected bank will be 58 per cent of the closed-delta connection or 87 per cent of the rated capacity of the two transformers used in the open-delta connection. Inasmuch as the primaries of two transformers are connected in parallel to make one leg of the open-delta connection, we may consider each leg as having 50 kva. transformer load connected thereto. Then 87 per cent of $(50+50) = 87$ kva.

The current loads will be equal when the three-phase load is balanced. The safe primary current will be about 22.5 amp. per terminal or twice the current rating of one transformer, if the nameplate indicates primary amperes. The safe secondary current will be about 113.5 amp., which is approximately the

ampere rating of one transformer when connected for 220 volts. A system of this kind should only be used temporarily, because of the low efficiency and poor power factor of this connection.

ALEXANDER MCLENNAN.
Westinghouse Elec. & Mfg. Co.,
Pittsburgh, Pa.

* * * *

At a normal high-tension rating of 2,200 volts, a primary current of 11.4 amp. will be taken by each 25-kva. transformer; the secondary current delivered by each pair of transformers at 440 volts would be approximately 114 amp.

Addition of two more transformers similarly connected would form a closed delta connection and give the bank a rating of 150 kva. In this case, with a line potential of 2,200 volts, the line current will be 39.5 amp. and the phase current or the current in the high-tension winding of each transformer will be 22.8 amp. However, as now connected (open delta), the line current and the phase current are the same and the capacity of the bank is limited to 22.8 amp. on the primary side, with a line current of 114 amp. on the 440-volt secondary.

West Allis, Wis. EDWARD JAMES.

* * * *

The diagram of connections given by J. M. M. shows what may be considered to be two 50-kva. transformers connected in V or open-delta. Since the full line current must flow through each transformer the capacity of the total bank for safe normal load operation will be only 86.6 per cent of the actual capacity or 86.6 kva.

The normal safe line current will be as follows: 2,200-volt side, 22.7 amp.; 440-volt side, 113.5 amp. These values do not include any allowance on the 2,200-volt side for core loss current which will increase the figure of 22.7 amp., to 23.5 or 24 amp. for commercial transformers.

Care should be used when connecting the 2,200-volt windings to see that all the voltage connections are the same and that no taps are used, which might give either a higher or lower voltage value.

C. OTTO VON DANNENBERG.
Designing Engineer,
Sanderson & Porter,
Springdale, Pa.

* * * *

In answer to the question asked by J. M. M., I wish to submit the following: The connection shown is an open-delta connection, and will deliver 86.6 per cent of the nameplate rating of the transformers in the open delta connection or 57.7 per cent of the power that would be delivered from a closed delta connection having six 25-kva. transformers connected two in parallel. The closed delta capacity would be 6×25 kva.=150 kva. The open-delta capacity is 150×57.7 per cent=86.6 kva. The nameplate rating of each transformer is 25 kva. which multiplied by 86.6 per cent gives us 86.6 kva.

The current in a three-phase system =(kva.×1,000)÷(line voltage×1.732). In this case the full-load primary current=(86.6×1,000)÷(2,200×1,732) =22.7 amp.

As the secondary voltage is one-fifth of the primary voltage, the secondary current must be five times the primary current; that is, 113.5 amp.

As the efficiency of a transformer is never 100 per cent, the secondary current will be somewhat less than 113.5 amp. These values are safe.

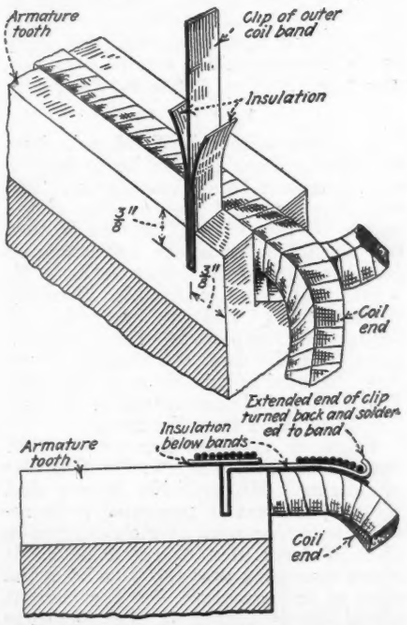
Ustick, Idaho. ALEX BREMNER, JR.

* * * *

Armature Bands Overheat.—Five bands are used on a 220-volt, d. c. armature with which we are having trouble. The armature coils slope very sharply and to prevent the outside bands from slipping off the ends of the armature, the winder soldered copper strips across the bands so as to tie them together. Six ⅝-in. strips were placed parallel to the coils and spaced at equal distances around the armature. The bands as well as the copper strips are well insulated from the armature winding, but the bands and particularly the copper strips become very hot, presumably from some induced current. I would like to know what causes this heating and how it may be prevented. If it is induced current that causes the heating please explain what causes this current. Is there any way in which I can tie these bands together that will not cause the heating referred to?

Oelwein, Ia. L. T. M.

In reply to the question of L. T. M., I am positive that his trouble is due to induced currents in the band connections; he has a squirrel-cage effect from the method of banding that he is using. I have found good results from the following method of fastening end bands so as to prevent them from slipping off the coils, in cases where the coil ends slant to a considerable extent.



Method of anchoring end bands that are inclined to slip off end of armature.

In a tooth, a slot is cut wide enough to take the thickness of the clip and a thickness of insulation on each side of it, as shown in the top illustration. Insulation for the bands is then put on in the regular manner and the clips bent over the insulation, the bands run on, and soldered to the clips, as shown in the bottom illustration.

After removing the bands from the coil ends, mark off places on the outer edge of the core at points on the teeth where the coil band wire clips should come. These points should be located about ⅜ in. from the outer edge of the tooth. Now in some convenient way, as with a file, cut down the surface of the marked teeth to a depth of ⅜ in. and to a width equal to the thickness of the band wire tie clip and two thicknesses of insulation, as is shown in the top diagram of the accompanying illustration. After this has been done to all of the teeth that were marked, separate the laminations with a small, sharp-pointed chisel in each tooth, as is shown in the illustration.

Then insert in the small slot, one end of the band wire clip with insulation on each side of it, letting the band wire clip stand vertical as shown in the top illustration. Prepare the surface of the coil ends with insulation to receive the band wire. After this is done, bend the clip to a horizontal position. These band wire clips should be made long enough so that when they are bent over with one end insulated in the slot in a tooth, the other end of the clip will extend about ¼ in. beyond the edge of the band wire. After the band wire has been wound on, the extending end of the clip may be turned back over the band wire and soldered in the usual manner, as shown in the bottom illustration.

We are now ready to lay on the special band; that is, the one that is shown at the left in the bottom illustration. This is a core band. See that insulation of suitable thickness is placed over the outer end of the core. One edge of this insulation should project about ¼ in. beyond the edge of the core so as to allow the band wire to be put on as near the edge of the core as practicable and thereby hold the inserted end of the outside band clip from raising and coming out of the small slot in the tooth. Careful examination of the bottom illustration will show how the clips holding the band going over the coil ends are anchored in the teeth of the core by the core band.

I. F. WISINSKI.
Chicago Elevator & Electric Mach. Co.,
Chicago, Ill.

* * * *

L. T. M.'s trouble is rather common, but he has an aggravated case because of the copper strips with which he has tied together the armature bands. Ordinary banding heats an armature in two ways: First, by losses in the bands; and second, by restricting the ventilation and preventing the dissipation of heat from the armature core and coils.

According to T. Spooner, in the January, 1926, number of the *Journal of the A. I. E. E.*, band losses may be classified as follows: (1) Eddy current losses in band wires, solder, and tinned strips, due to radial flux. (2) Eddy current losses in band wires, solder, and tinned strips, due to tangential flux. (3) Normal hysteresis loss in band wires and strips due to tangential flux. (4) Additional hysteresis losses due to displaced hysteresis loops. (5) Additional armature tooth

loss (eddy currents) due to the damping out of the flux by the bands in the region of the pole tips, thus producing flux across the laminations, which may result in extra eddy current losses.

Mr. Spooner also gives the following factors as affecting band losses: (*a*) Width of bands; (*b*) Width of teeth at air gap; (*c*) Size of band wires; (*d*) Amount of solder used; (*e*) Dimensions of tinned strips and clips; (*f*) Normal resistivity of wire, solder, and tinned strips; (*g*) Temperature of bands; (*h*) Frequency; (*i*) Induction, in both teeth and bands; (*j*) Field form; (*k*) Air gap; (*l*) Depth of band groove.

From the above it may be seen that armature banding is not such a simple thing as it seems. Band temperatures may run up to 200 deg. C., or more, and band losses may amount to 2 or 3 kw. under certain conditions.

Returning to fundamentals, however, when a conductor which is part of a closed circuit cuts through a field of magnetic flux, a current is induced in it. The direction of the current is at right-angles to the direction of the flux and at right-angles to the direction of motion of the conductor. This relationship may be remembered by the right-hand rule. Extend the figures in the direction of the flux (out of a north pole or into a south pole) with the palm of the hand directed so that the movement of the conductor will bring it into the grasp. The induced current will be in the direction of the thumb when parallel to the conductor.

It is by induction that the current is set up in the coils of a generator. The relative movement between the flux and the conductor produces the flow. In a d.c. generator the conductors move through the flux, but in an a.c. generator the flux moves across the conductors; the result is the same in either case, as lines of magnetic force are cut by the conductor. As the conductor passes under a north pole the current flow will be in a given direction; then as the conductor moves under a south pole the current flow is in the reverse direction. This causes the generation of alternating current.

Consider the rotor of a squirrel-cage motor. In it there are a number of conductors across the face of the core from end to end and embedded in slots. These are connected together by end rings which may be of low or high resistance depending upon the work for which the motor was designed. This motor operates because of the induced current in the rotor conductors, which sets up magnetic fields of flux which are linked with the conductors.

L. T. M. has, in effect, constructed a squirrel-cage winding, with very high resistance rings, over the armature winding of his motor. Currents are induced in the copper strips and bands, which produce heating by ohmic resistance. Even if the bands were not connected together, there would be some losses due to this cause, as indicated in points (1) and (2), in the fore part of this discussion. For this reason the bands are made of wire instead of strap and they are usually made narrow and insulated from each other.

Points (3), (4), and (5) in the preceding, cover losses due to reversing magnetism setting up internal stresses in the steel parts, thus causing heating. Attempts have been made to use non-magnetic materials for banding but no satisfactory results have been obtained because of the strength required of the bands.

Armature bands must be kept from contact with the armature core. When coils or wedges are not high enough to do this, insulation should be put under the bands; otherwise, closed circuits will be formed by the rings, laminations of the core, and the armature shaft.

The bands should not be connected together for the reasons set forth in the preceding. It is believed that if the coils are properly placed in the slots and the bands wound on with sufficient tension on the banding wire, there will be no slipping of the bands in the operation of the motor.

Electrical Engineer, D. W. BLAKESLEE.
Jones & Laughlin Steel Corporation,
Pittsburgh, Pa.

* * * *

In reply to the question by L. T. M., the heating of the copper ties is caused by heavy induced current. These ties in conjunction with the band act as a shorted coil of one turn and low resistance, with a consequent heavy current flowing through it.

To prevent this induced current, the copper ties can be placed at points around the armature where they will be under like poles at the same instant, with the result that little or no voltage will be induced.

In a four-pole machine we are limited to two ties, in a six-pole machine, three ties, and so on. The number of ties equals the number of poles divided by two, and must be spaced accurately to obtain the desired results.

Brooklyn, N. Y. MICHAEL REUTER.

* * * *

In a recent issue L. T. M. asks how to remedy some trouble he is having with armature bands heating on a 220-volt, direct-current motor. One of the causes of this kind of trouble is that the armature bands are not insulated from the core of the armature. L. T. M. writes that they are insulated from the winding, but that in itself is not enough, for the band must also be insulated from the core. We frequently run into this kind of trouble in a shop that I operate and always correct it by insulating the band from the core.

There is also another source that may cause the trouble L. T. M. is experiencing. He probably knows that the way current is generated is to revolve a copper wire at right angles to lines of force in a magnetic field. It is not necessary that the wire be in the slots of the armature, for the current would be generated if the armature coils were fastened to the outside of the armature. It is also known that if an armature coil is wound through the slots of an armature and the ends of the coil tied together, the coil will heat and burn the insulation.

What L. T. M.'s armature winder does when he ties the bands together, is to put on the outside of the core of the armature a copper wire, or rather five of them, that cut lines of force in a magnetic field which causes a current to flow through them. The band wire completes the circuit through the copper tie strips. The current induced in these strips causes them to heat and melt the solder on the bands. To correct the trouble that he is experiencing, he will have to insulate the copper tie strips from the banding wire.

Norton, Va. WILLIAM HANKS.

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Answering L. T. M.'s question, I would say that the reason the banding wire on the armature heats up is on account of the strips of copper being parallel to the armature coils. When the armature is rotating, these strips of copper are cutting lines of force the same as the armature coils, and since these strips are connected together by means of the core band, a path is made for the induced current to flow and thereby cause the tie strips of copper and the core band to heat.

If L. T. M. would fasten the strips of copper from the end band to the first core band and not to all of the five bands, I have no doubt that he will not have any more trouble from hot band wires. CHARLES H. MCSPERRITT.
Newark, N. J.

* * * *

Not knowing the horsepower and revolutions per minute of L. T. M.'s motor, about the quickest way to remedy his trouble is to use a non-magnetic banding wire, such as bronze or piano wire. If he cannot get this kind of wire, he can successfully use steel banding wire even though it is a magnetic material. He can overcome the heating due to magnetic action by using as few turns of banding wire as the speed and size of the armature will permit. With a total of five bands, the core bands should not be connected together with strips; however, the end core bands can be connected with a clip to the end coil bands.

Ninety per cent of all band failures are due to loose bands from poor soldering, from too wide a band on the core, and from end coil bands not being put on properly. The end coil bands whenever possible should be located in a hollowed-out position or sort of valley in the middle of the coil ends. End coil bands should be kept as far away from the core as possible in order to secure the best results. The larger the size of the banding wire the better, but make sure that the core bands are not too wide or too heavy.

A way of getting around the heating of bands is to separate the individual wires by putting a piece of cord between each turn of band wire. The result is that a band is wound on having each alternate turn made of cord. Now remove the cord and pull the wires together only at the clips and solder them well.

Always remember that a band should never be grounded to the windings of the armature.

Newark, N. J. SAMUEL CARBAT.

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Answering L. T. M. there are probably two reasons why the bands on the armature in question heat up. The first and most important reason

is that since the copper strips lie parallel to the armature conductors, a current of low voltage and high amperage is induced therein. The circuit is closed through the bands, making several parallel circuits. The other reason is due to eddy currents being set up in the first band next to the core due to the radial (magnetic) flux between poles. While usually this is not considered very seriously it may have quite an appreciable value due to the manner in which the bands are tied together in this particular instance.

There are three ways of overcoming the trouble. The first is to put the usual steel band at the end of the core and start a string band (we use seine twine) at the small end of the winding, making a solid band nearly up to the steel band. If trouble is experienced in starting the band, a few turns of friction tape may be put on at the starting point in such a manner as to make a flat place for the start. The string should be well saturated with varnish after it is put on, two coats usually being required. A second method is to build up two flat places about ¾ in. or 1 in. wide on the slanting surface, with friction tape and heavy fish paper, these being held from slipping by strips brought from the top band in the same manner as L. T. M. used on his bands. Note that the strips are used only to keep the built-up material from slipping and must be insulated from the bands themselves. A third method is to build up the space under the leads with suitable material so that when the leads are laid they will lie nearly parallel with the axis of the armature for a length sufficient for proper banding. Obviously the latter method is not practicable except when the armature is being rewound.

We use the first method on one type of armature; it makes a fairly neat looking job and if the string band is well saturated with varnish and dried, it will properly hold the conductors and the band will not come off.

A quick-drying, emergency compound for saturating the string band may be made by dissolving powdered rosin in alcohol, using an old egg beater for mixing. The alcohol can be evaporated in a few minutes by an air blast after which heat should be applied for about ½ hr. with a space heater or otherwise; the rosin will harden as the armature cools. L. T. M. asks what causes the current to flow in the bands. This is caused by induction in the same manner as the secondary winding of a transformer is energized by the primary, the current in the armature conductors being, of course, alternating. Briefly the action is as follows: When an alternating current passes along a conductor it sets up a magnetic flux around it which increases in value. A good analogy of this is the expansion and contraction of the hairspring in a watch or an alarm clock. This flux encircles any other conductor in the immediate vicinity, passing by it first in one direction and then the other, thereby setting up an induced electromotive force therein. This electromotive force causes a current to flow through the closed circuit that L. T. M. has provided by tying the bands together with copper strips. This current causes the heat that he is seeking a remedy for.

A more complete description of how voltages are induced as described in the foregoing, may be found in "Elements of Electricity" by Timbie and "Lessons in Practical Electricity" by Swoop.

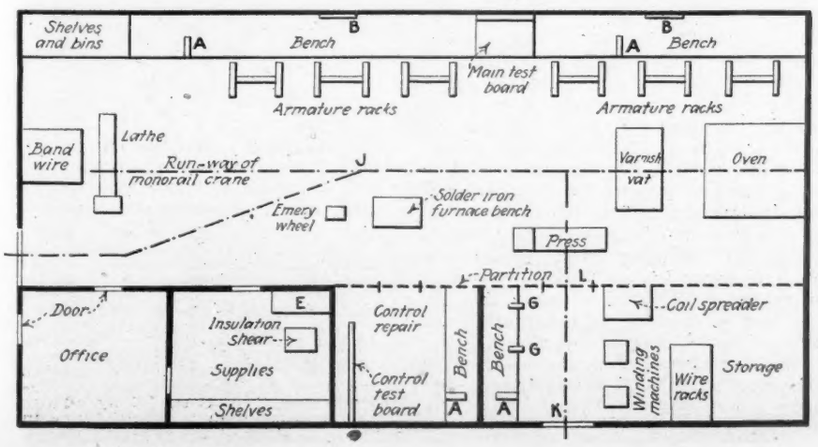
CHESTER A. WILLIAMS.
Electrical Dept.,
Providence Gas Co.,
Providence, R. I.

* * * *

Laying Out Electric Repair Shop for Steel Plant.—We are planning to build a new shop for doing our electric repair work. This shop will handle the necessary repairs on motors and control in a steel plant having about 1,000 modern motors both a. c. and d. c. During normal operation 14 men are required in the shop. Naturally the shop will have a coil-winding section; so provision must be made for winding equipment and supplies. In addition there will be a lathe, insulation cutting shear, baking oven, armature press, test rack and other shop equipment. I would like to obtain the views of readers as to what would be the most practical layout of a repair shop for this class of work. Possibly they have found certain arrangements of repair shop equipment that have produced money-saving results.

Indiana Harbor, Ind. A. R. D.

In answer to the question by A. R. D., I would like to offer the accompanying sketch of a shop layout, which combines the best points of several repair shops that I have seen. In this sketch the dotted line is a partition which may or may not be put in, according to the ideas of the management. I believe, however, that it will pay to put it in because of the fact that each department is thereby isolated and the distractions due to testing will not affect any other department.



A in the sketch represents a bench vise, four of which are shown; of course, it is not absolutely necessary to have this number, but they will save time, when installed at the positions shown. *B* is a small testing board which consists of a buzzer with series test leads; four pony receptacles, wired series-multiple; and series-test leads for testing d.c. armatures with a telephone receiver, if this method is to be used. All high-voltage tests will be made at the main test board which should be arranged so that 5,000 volts a.c. may be obtained for ground tests on 2,200-volt equipment. Likewise, a.c. and d.c. voltages should be on the board to test motors used or repaired in the plant. A large growler should be suspended overhead for testing d.c. armatures for shorts and partial shorts. The emery wheel stand and bench for supporting the furnace for heating soldering irons are shown in a central location. *E* is an insulation rack in front of which is the insulation shear (note that this shear is in the supply room). A man or boy should be in charge of this supply room, who is capable of cutting insulation to winders' measurements and the cutting waste should be used on small jobs. This man can, in his spare time, also lay in a stock of insulation cut to the sizes most frequently used. *G* indicates taping machines for coils.

A monorail, shown here in dotted lines, with two 1-ton blocks will be necessary. It will be advisable to put a switch in this monorail, as shown at *J*. *K* is an outer door which should be able to accommodate with plenty of clearance, the largest apparatus which has to be repaired. *L* is a small door in the coil department for the convenience of the men who strip and clean coils that are to be rewound. Small stators can also be burned out conveniently in this part of the shop. One or more racks should be provided for coils that are to be dipped. These coils can be handled by the chain block on the press monorail and shunted to the main monorail by aid of another block. The band wire is racked behind the lathe entirely out of the way. Unless the lathe is reversible, one or more rollers will be necessary on the apron to bring the wire to the front for banding.

The shop should be well lighted, warm in winter and as cool as possible in summer. Winding is tedious work under the best of conditions and the nearer ideal conditions are obtained, the greater the capacity of the workmen. Six armature racks are shown, which should have rollers about 4 in. in diameter and should be adjustable as to length. One or more heavy tables should also be provided for supporting stators while being rewound.

GRADY H. EMERSON.
Birmingham, Ala.

Due to the convenient arrangement of equipment, this electric shop layout will save time of workmen and speed up repair operations.

Electrical Service

around the works

For this section short articles describing ideas and practical methods devised to meet particular operating conditions are invited from readers. The items may refer to inspection, overhauling, testing, and emergency or special installations.

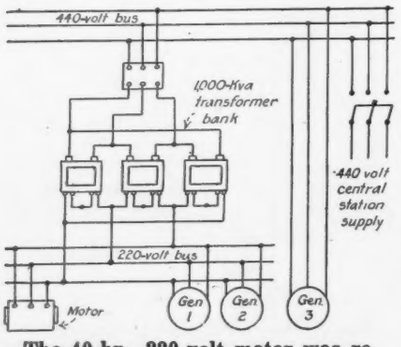
Saving Made by Elimination of Lightly Loaded Transformer Bank

FOR industrial plants which generate their own power during the day, and purchase auxiliary power for night lighting or occasional motor use, it is advisable from an economic standpoint to have the motors that are used at night of the same voltage as that of the central station supply, as will be illustrated in the following example.

The power supply of a certain large industrial plant was as shown in the accompanying diagram. Generators *1* and *2* were both rated 220 volts, three-phase, while generator *3* was a 440-volt, three-phase machine. The connected plant load consisted principally of 220- and 440-volt motors. This arrangement was the result of combining old and new equipment and was designed with the idea of ultimately changing entirely to 440-volt service.

It was found necessary on certain work to operate a 40-hp., 220-volt motor for 14 hr. each night over a period of several years. This necessitated operating one of the 220-volt generators at night or using purchased power which was already in use in the plant. Naturally it was much cheaper to use the purchased power, however this power was supplied at 440 volts and since the motor was rated at 220 volts, using purchased power necessitated switching in the 1,000-kva. transformer bank normally used for changing the voltage from 440 to 220.

Through the use of an indicating wattmeter on the central station power feeder, it was found that at very light loads the transformer bank had an excitation load of 16 kw. This represented a waste of power that could be avoided by the use of a 440-volt motor, as it would then not be necessary to use the transformer bank at night.



The 40-hp., 220-volt motor was reconnected for 440 volts and fed from the 440-volt bus, thereby eliminating the transformer bank.

Accordingly, the connection of the stator coils was changed from parallel to series, and the motor cables were tapped onto the 440-volt feeder.

The saving made possible by elimination of the use of the transformers was $16 \times 14 \times 0.031$ (cost per kw.) $\times 300$, or $2,082 per year. The labor and material cost for reconnecting the motor was approximately $65. A better power factor was obtained and the line losses between the motor and switchboard were also decreased somewhat.

Jersey City, N. J. E. A. BAERER.

Loss of Torque in Changing Squirrel-Cage Motor to Wound Rotor Design

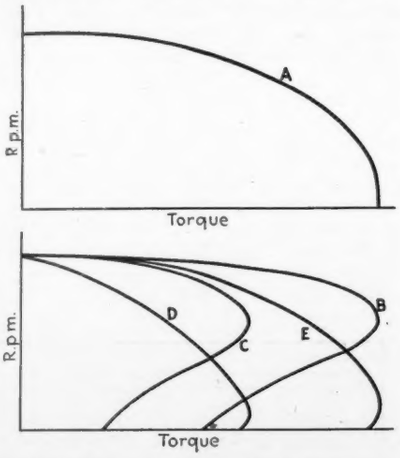
IN ONE power plant a KTR, 30-hp. motor was used to operate a coal hoist. It was desired to change this over to a slip-ring motor by using a new rotor, and obtain the same maximum torque value. A high-resistance motor like the KTR has a secondary resistance of such value that its starting torque is very nearly equal to its maximum torque and the speed-torque characteristics are similar to curve *A* in the diagram. Any decrease in the rotor resistance would decrease the starting torque, although the maximum torque would remain the same. Such a condition is shown by curve *B*.

It might be expected that the new, low-resistance, slip-ring rotor would give a torque similar to curve *B*. By inserting the proper value of resistance in the motor secondary one might assume that a torque curve such as *E*, would be obtained, which would be practically identical with curve *A*. The only difference would be that in curve *A* the secondary resistance is contained in the high-resistance rotor of the squirrel-cage motor and in curve *E* the resistance is external to the motor, being contained in the resistance boxes of the slip-ring motor. This is a natural assumption because the maximum torque of an induction motor is independent of the secondary resistance. The starting torque varies only with changes in the secondary resistance, irrespective of whether this resistance is internal or external to the secondary winding of the motor.

As a matter of fact, the basic curve obtained with the low-resistance, slip-ring motor is shown at *C*. Inserting the proper amount of resistance in the secondary gives a maximum starting torque, as indicated by curve *D*, which is considerably less than indicated by curve *B*. The reasons for this will be explained.

First, the squirrel-cage rotor has its rotor bars short-circuited by end rings, whereas the wound rotor has end connections which cause self inductance.

Second, the construction of the squirrel-cage rotor is such that the minimum possible air gap is maintained, whereas the wound-rotor winding is imbedded in the rotor iron and the air gap is increased due to the presence of insulation and wedges. The net result is that there is a considerable decrease in the flux of the motor. Decreasing the flux of an induction motor decreases the maximum torque obtainable as is indicated by curves *C* and *D*. In order to obtain a torque more nearly equal to curve *A*, it would be necessary to rewind the stator with a winding having lower losses, which would increase the flux. Rewinding of the stator would improve the torque characteristics to a certain extent, but would not bring the maximum torque up to the original value obtained with the squirrel-cage rotor, due to the inherent characteristics of the wound



Speed-torque characteristics of high-resistance squirrel-cage motor, and wound-rotor motor with resistance added to secondary winding.

The speed-torque curve of a high-resistance, squirrel-cage motor is shown at *A*. The effect of decreasing the squirrel-cage rotor resistance is shown in curve *B*. *C* is the basic curve of a low-resistance, slip-ring motor, and *D* is the curve obtained after inserting resistance in the secondary circuit. Curve *E* represents the speed-torque values which it might erroneously be assumed could be obtained by adding the proper amount of resistance in the secondary of the slip-ring motor.

rotor as was previously mentioned.

It should also be noted that the starting torque of a wound-rotor motor will be less than that of a squirrel-cage motor because of the positional factor. Also, due to the bars of a squirrel-cage motor being short-circuited, the torque at one position of the rotor will be practically the same as at any other position. If torque is an important consideration when it is desired to change a squirrel-cage motor to a slip-ring motor by changing rotors, it is important that the new torque characteristics be checked by the designing engineers of the company which manufactures the motor in question.

R. F. EMERSON.

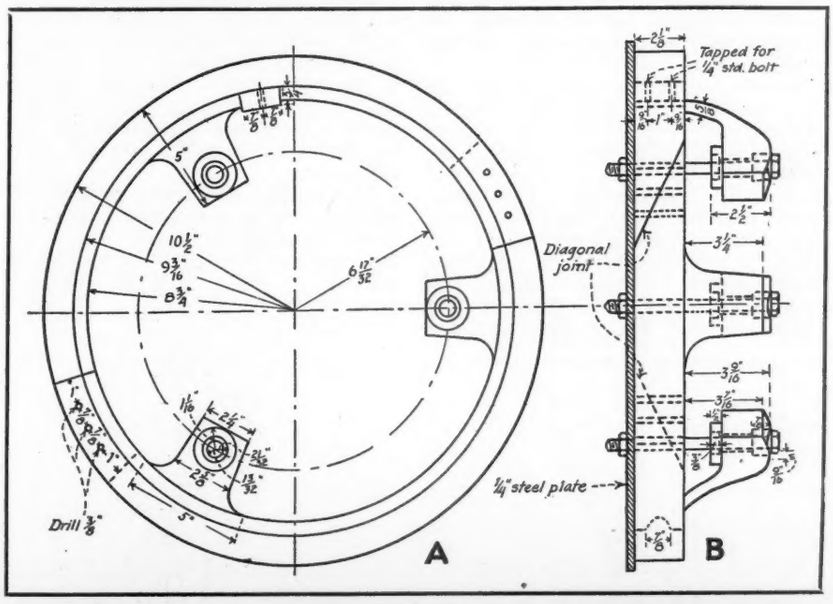
Industrial Engineering Dept.,
General Electric Co.,
Schenectady, N. Y.

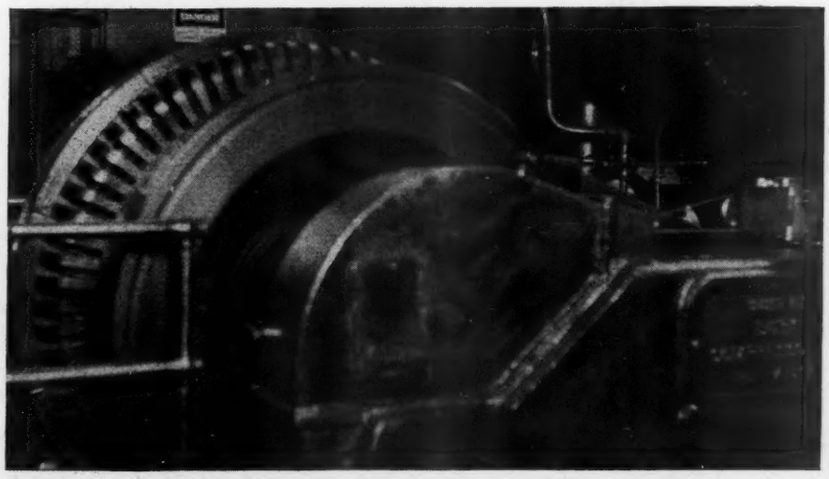
Method of Replacing Motor Collector Ring Under Difficulties

THE AIR compressor shown in the illustration has been in service four years, and is driven by a 200-hp., three-phase, 60-cycle, 2,300-volt, 250-r.p.m., synchronous-type motor with 125-volt excitation. The rotor shaft of the motor carries the flywheel and pulley for the belted exciter, the collector rings and the eccentric arms, all on the same end. The collector rings on the rotor are of the solid type and are bolted on the spider by projecting bolts at three points on each ring. These rings are made of cast iron, chilled on the wearing surface.

About six months ago the inside ring on this compressor motor developed several flat spots. We tried every means of grinding the ring by using a portable grinder with carborundum wheels and several makes of hand stones which were guaranteed to cut chilled, cast iron, but failed to do so in this case. We tried a cutting tool on this ring and belted the rotor to a variable-speed motor so that various cutting speeds could be obtained, but the tool failed to cut this ring at any speed available. Of course, we were handicapped from the beginning because of the small space available, as can be noted in the illustration.

This shows, A, dimensions of brass collector ring, with location of bolt holes for joints and, B, ring mounted on steel plate which served as templet after ring was cut in two. The problem of replacing a collector ring on this air compressor motor, without dismantling the outfit, was solved by installing a split, brass ring.





It was decided that the ring had to be taken out, but operations would not permit shutting down the motor long enough to remove the rotor; besides there was no lathe in this vicinity large enough to swing a rotor of this diameter. In addition to this, the flywheel pulley and eccentric arms would have to be pressed off the rotor shaft. We consulted the manufacturer of this motor about purchasing split rings, hoping to be able to install them without removing the rotor. The manufacturer advised that the design would not allow sufficient space for the usual type of split joint because of interference from the projecting spider bolts. So we decided to purchase from the manufacturer a solid brass ring made from the original pattern previously used for the cast-iron rings, and after receiving it we proceeded to cut joints in it. The dimensions of the ring are shown in *A* of the illustration.

The ring was first bolted to a piece of ¼-in. steel plate and joint bolt holes drilled, as shown in *B*. We then removed the ring from the steel plate and sawed diagonal joints in it, as shown, after which we mounted the ring on the plate again and added sufficient fillers to the joints to bring the outside diameter to the original size. Next we removed the good cast-iron ring on the compressor motor from its spider and placed it to one side on the shaft. After this we wrecked the old cast-iron ring with a hammer, installed the new brass ring and put the good cast-iron ring in place again. We found that the brass ring was out of round not quite 1/32 in. It was a small matter to grind the ring true at the normal speed of the motor, with either the hand stones or grinding wheels available. The job was completed in about 6 hr. and the compressor was put back on the line immediately. To date, the new ring has given perfect satisfaction.

Chief Electrician, J. S. MURRAY.
Follansbee Bros. Co.,
Toronto, Ohio.

Factors That Affect Safe Current Carrying Capacity of Copper Wire

THE proper size of wire to use for any current value is decided after consideration of at least one of three factors. These three factors are: the voltage drop in the wire, the value of the power lost in the wire, and the temperature rise because of this power loss. The first two of these items will vary directly as the resistance of the wire, but temperature rise depends not only upon the resistance, but also upon the ability of the wire to dissipate the heat that is generated within it.

The resistance of two wires, if they are made from metal of the same specific conductivity will vary inversely as their cross-section area. However, the ability to radiate heat will depend to a great extent upon the surface area which will vary as the circumference for wires of the same length. The cross-

section area of wire will vary as the square of its diameter, while the circumference varies directly with the diameter. Therefore, the radiating surface does not increase nearly as fast as the cross-section area and for this reason large wires cannot carry the same ratio of current in proportion to their circ. mil area as smaller ones.

An example of this decrease in the safe current carrying capacity as the wires become larger, may be found in a table prepared by the National Board of Fire Underwriters. According to this table, No. 14 wire with an area of 4,000 circ. mils has a carrying capacity of 15 amp. for rubber insulation, 18 amp. for varnished cloth and 20 amp. for all other insulation. This gives an average between 4 and 5 amp. per 1,000 circ. mils. For a wire area of 2,000,000 circ. mils, the carrying capacity averages around 1,300 amp., or has decreased to less than ¾ amp. per 1,000 circ. mil for the different insulated wires of this size.

Many electricians judge the safe-current-carrying capacity of a cable by the current density, that is, the number of amperes per 1,000 or per 1,000,000 circ. mils. As may be seen from the example given above, this is poor practice, since the safe current density decreases with the size of the wire.

G. H. McKELWAY.
Westfield, New Jersey.

Method of Checking Alignment of Bridge on Traveling Crane

TO PERMIT smooth operation, the track wheels on the bridge of a traveling crane and, in particular, the driving track wheels, must sit squarely with the rails. If the wheels are out of line with the rails, excessive binding will occur at the wheel flanges which will cause undue wear and may result in breakage of the wheels.

To maintain proper alignment, the drive wheels must be of the same diameter. One-eighth inch difference in diameter of two wheels driven from a common shaft will cause one side of the crane to advance more than ⅜ in. for each revolution of the drive wheels. Considering a 2-ft. wheel, this means an advance of 6¼ in. in 100 ft. of travel. In other words, with this difference in diameter between two wheels, one side of the crane will travel one-half of one per cent further than the other.

The diameter of all driving wheels on cranes should be frequently checked. On account of the limited room for measuring this diameter, it will usually be found most convenient to measure the circumference of the wheel by putting a steel tape around it. The circumferences of the wheels may thereby be directly compared. This is really more accurate than comparing the diameters of the different wheels.

Drive wheels found to have slightly different diameters must be replaced. We always match up our drive wheels in pairs, and consequently install them in pairs. Also, all new wheels are purchased in pairs. All wheels removed are checked for actual diameter, flat spots, and similar evidences of wear. Wheels with flat spots requiring the removal of $\frac{1}{16}$ in. to ⅛ in. of material to bring them back to round, are ground. It costs us about $6 to remove ⅛ in. of metal. The chill is usable for about ¼ in.; so we are usually able to grind off up to ⅛ in. without going beyond the chilled surface on the wheel tread. Wheels are ground to match some other wheel if possible. Unmatched wheels are used for idlers.

Another common cause of misalignment, is from the slipping of the wheels in operation, due particularly to rapid deceleration and acceleration of the crane bridge. The crane should occasionally be run against the end bumpers to bring it back to square. However, to obtain any benefit from this, the bumpers must be kept rigid and carefully aligned so as to bring the crane bridge at right angles to the crane runway.

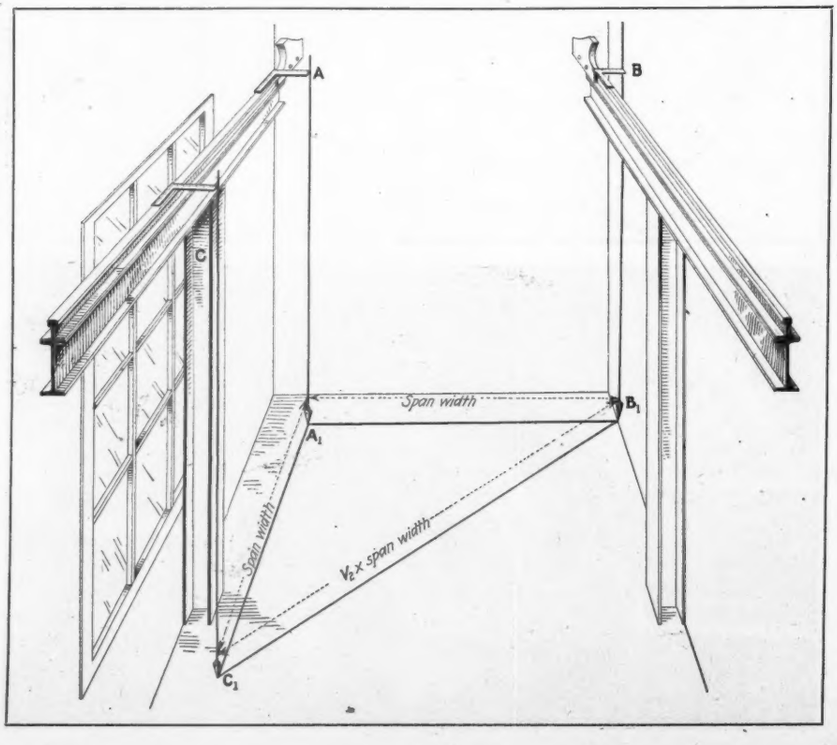
For checking the alignment of the bumpers, we have used the following method with very good results. Plumb bobs are dropped from each of the bumpers to the floor, as shown at *A* and at *B* in the accompanying illustration. Inasmuch as the rails on the runway prevent dropping the plumb bobs directly from the bumpers, a carpenter's square is placed against the bumpers and the plumb bobs dropped from the corner of the square as shown in the illustration. The distance from the center of the rail to the end of the square should be the same in every case where the square is used. In other words, the distance from the center of the rail to point *A* should be the same as the distance from the center of the other rail to point *B*; likewise, it should also equal the distance from the center of the first rail to point *C*. This will locate the points A_1, and B_1 on the floor beneath the crane runway. This distance is equal to the distance between the centers of the rails and is known as the span width. Now from the end of the bumper at the left, as shown in the illustration, measure down the rail a distance equal to the span width, as shown at *C*. By use of a square, drop a plumb bob from this point to the floor as at C_1.

We now have an isosceles triangle laid out on the floor as at C_1, A_1, B_1. If the angle at A_1 is a right angle then the bumpers are so placed as to bring the crane bridge to a right angle to the track runway; in other words, the end bumpers are properly aligned. If the angle at A_1 is a right angle, the distance from C_1 to B_1 will be equal to the span width multiplied by the square root of 2, or multiplied by 1.4142.

If this distance does not check, the point B_1 should be moved until it is at a distance from C_1 equal to the span width multiplied by the square root of 2, and also at a distance from A_1 equal to the span width. The new B_1 may now be projected up to the end bumper above it by means of a plumb bob, and the end bumper moved until it is in alignment.

This method may sound very complicated, but when it is actually tried out, it will be found to be very simple and the results obtained will be well worth while.

R. N. VINING.
Electrical Engineer,
Detroit Seamless Steel Tubes Co.,
Detroit, Mich.



For correct alignment, a line connecting the end bumpers should be at right angles to the rails.

By means of carpenters' squares and plumb bobs the span width *AB* is laid out on the floor, as shown at A_1 and B_1. Likewise, a distance equal to the span width is laid out on the rails at *A* to *C*, or as shown on the floor between A_1 and C_1. For the angle at A_1 to be a right angle the distance between C_1 and B_1 must be equal to the span width times the constant 1.4142.

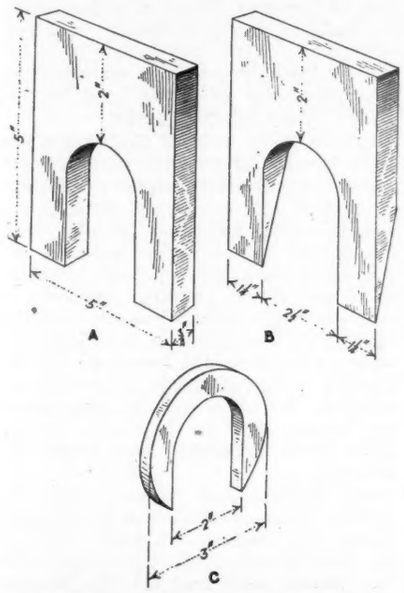
Mechanical maintenance of

Power Drives

This department will furnish mechanical details of installation, operation and maintenance of equipment in the path of power service from the first mechanical driving element through the auxiliary transmitting equipment to all driven machines.

Set of Wedges for Driving Pinion from Shaft

THE accompanying sketches show a set of wedges which I have used for driving off motor pinions where the space between the bearing and the pinion is too small to permit the use of a puller or a key-drift. These wedges consist of a flat steel plate with an opening as shown. A set consists of several wedges of the form shown as *A* and one tapering wedge *B* used for starting. All of these are of the same thickness. The tapered wedge *B* is driven in the full distance, removed, a straight wedge of the form *A* inserted, and the wedge *B* again driven in. Or, if preferred, a puller may be used after the pinion is started.



The set of wedges, A and B, are used to drive off motor pinions when they are very close to the bearing. The washer, C, is used to reinforce paper pulleys before using a puller or these wedges.

The wedges for use on a 25-hp. motor were made from a piece of steel 5 in. square and ¾ in. thick. This set is shown in the sketch. Wedges of proportionate size would be used on smaller shafts. With these wedges, the pinion on a 25-hp. motor was removed in a few minutes, although it had for several hours resisted all efforts to remove it by other means.

Another difficult problem is the removal of very tight paper pulleys by a puller, as the strain may loosen the fibrous body of the pulley from the hub. By using a slotted washer *C* against the end of the hub of the pulley to bring it flush with the edge, the strain is taken off the body of the pulley and transmitted to the hub. With this washer, either the wedges or a puller may be used on paper pulleys.

E. E. G. ROBERTS.
Southern Manganese Corp.,
Anniston, Ala.

Easy Method of Aligning Parallel Shafts

ONE method which I have found convenient for aligning parallel shafts such as a lineshaft and a countershaft or jackshaft, is shown in the accompanying sketch. This device consists of a length of 2-in. by 2-in. lumber, which has been dressed on all four sides for convenience in handling and marking, and a short length of 2-in. by 2-in. angle iron, fastened to it to form a T as shown. The inner faces of the angle iron must be free from rough rust spots or dirt which would prevent it from fitting snugly against the shaft. Also, the stick should be mounted so that it is at right angles with the angle of the iron.

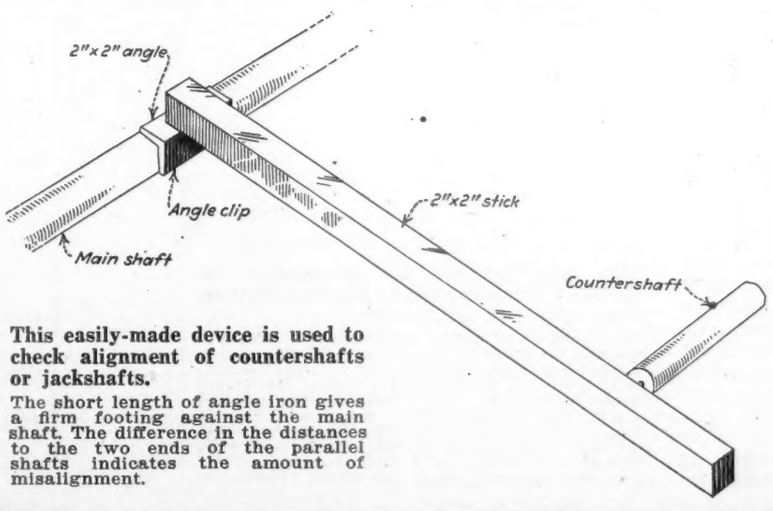
Wherever, it is possible to get at the ends of the countershaft or jackshaft, the angle iron is laid in place against the mainshaft as shown in the sketch, and the distance from the center or circumference of the countershaft or jackshaft is marked on the stick. This is repeated at the other end of the shaft and the distance between the two marks indicates the amount that the shaft is out of parallel. Correction for misalignment can be made with the adjusting screws at either or both ends of the shaft and the alignment again checked.

If the end of the countershaft or jackshaft is inaccessible, such as when it is in a bearing, the angle iron is laid against the main shaft as before, but the stick is placed across the top of the countershaft or jackshaft. The base of a carpenters' try-square is placed on the stick with the blade extending downward and pushed along until the blade comes in contact with the circumference of the countershaft. The position of the blade of the square is then marked on the stick and this line is compared with a similar line obtained at the other end of the countershaft. The difference between these line indicates how much it is out of alignment.

Before checking these alignments, the countershaft should, of course, be levelled. It is preferable to make these tests as near to the ends of the countershaft as possible, so as to get the greatest length possible between the checks.

This method has many advantages over attempting to use a string or laying a stick across the top of the two shafts and measuring with a try-square. The piece of angle iron need be only a few inches long and it is usually possible to find enough space on the main shaft free from pulleys to make these measurements.

MAURICE C. COCKSHOTT.
Hollywood, Calif.



This easily-made device is used to check alignment of countershafts or jackshafts.

The short length of angle iron gives a firm footing against the main shaft. The difference in the distances to the two ends of the parallel shafts indicates the amount of misalignment.

Estimating Horsepower Transmitted by Lineshafting

IN LAYING out lineshaft installations it is frequently desirable to make computations for different speeds and different sizes of shafting. Although this may be computed in each case, it is easier to determine the various capacities and ratings of different sizes of shafts at various speeds by the use of the accompanying chart. This chart was designed according to the following formula:

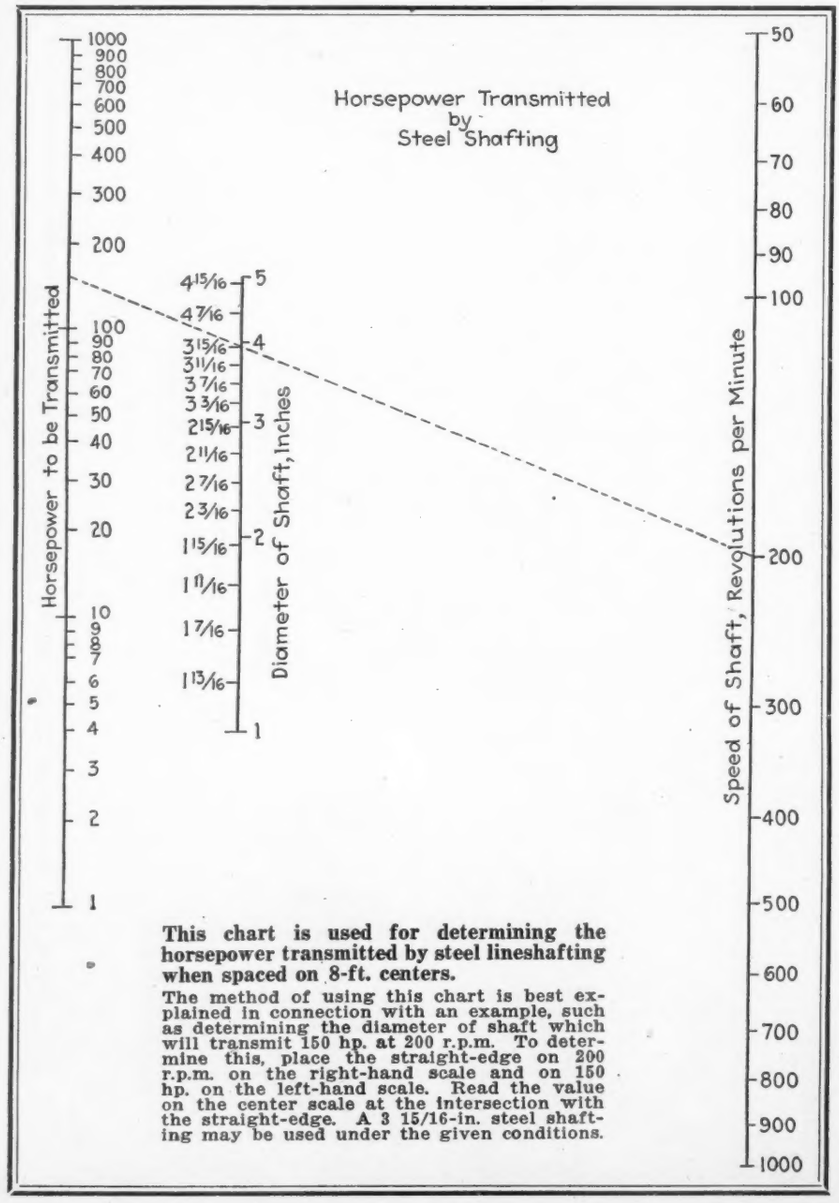
Diameter $= \sqrt[3]{[(\text{hp.} \times 80) \div \text{r.p.m.}]}$. This is a standard formula for determining the size of a lineshaft and applies only for standard construction where hangers are spaced on 8-ft. centers. The constant, 80, takes into account the installation of an ordinary number of pulleys driving machines and spaced within the 8-ft. centers. The main driving pulley should, of course, be on a section of shaft with the hangers placed closer together.

With this chart, horsepower transmitted, diameter of the shaft in inches, or speed of the shaft, may be determined if any two of the factors are known.

The scale on the left, horsepower to be transmitted, has values ranging from 1 hp. to 1,000 hp. The center scale, diameter of shaft in inches, is graduated in the more common sizes of shafts used. The right-hand scale gives the speed of the shaft in revolutions per minute, over a range of 50 r.p.m. to 1,000 r.p.m.

The chart is used as follows: Place a straight-edge across the chart on the two known values, such as the horsepower and speed; and the intersection of the straight-edge and the center scale will give the size of shaft to use for the given conditions. Obviously, if any two values are known the third may be found by placing the straight-edge on the two known qualities. The intersection of the straight-edge and the third scale is the unknown quantity.

CHAS. F. CAMERON.
Rock Springs, Wyo.



This chart is used for determining the horsepower transmitted by steel lineshafting when spaced on 8-ft. centers.

The method of using this chart is best explained in connection with an example, such as determining the diameter of shaft which will transmit 150 hp. at 200 r.p.m. To determine this, place the straight-edge on 200 r.p.m. on the right-hand scale and on 150 hp. on the left-hand scale. Read the value on the center scale at the intersection with the straight-edge. A 3 15/16-in. steel shafting may be used under the given conditions.

Selecting Proper Babbitt for Armature Bearings

BABBITT metals may be divided into lead-base and tin-base metals. The former finds far wider application on electric motors, as it is somewhat cheaper and gives very satisfactory service. The friction co-efficient is somewhat lower for lead-base babbitt, which is not quite so hard as tin-base babbitt. For general-purpose motors in coupled, belted, and ordinary geared service, the results are very satisfactory. Where very high speeds are encountered, tin-base babbitt is preferred, on account of its lesser tendency to "gall" or wipe.

Lead-base babbitt must be handled with great care; it has been found that the best temperature for handling this babbitt is around 460 to 490 deg. C. (860 to 914 deg. F.). If handled at temperatures much below the low point, segregation is likely to occur; if handled at higher temperatures and exposed to them for a considerable length of time, oxidation will occur and the metal may be ruined.

On motors used for severe service where vibrations are not only severe, but of a hammer-blow nature, it is preferable to use a bronze shell, tinned, and lined with babbitt, about 1/32 in. thick. The bronze is used for the purpose of insuring proper amalgamation, the babbitt being virtually soldered into place. With only a thin layer of babbitt, there is not much tendency for it to pound out of shape, as it is supported by the harder bronze.

Bronze shells without babbitt are not used to any great extent on electric motors. Bronze has a higher co-efficient of friction and expansion, requiring a larger bearing clearance than is used for babbitt. The higher friction co-efficient causes greater heat development and if the running clearance is held too small, it may happen that the bearing will be tight on the shaft and rotate with it in the housing. If the housing is strong enough to prevent expansion, the shell will be compressed and become tight on the shaft. On the other hand, expansion may break the housing.

The babbitt-lined, bronze shell insures a lower co-efficient of friction and hence less heating. In some cases, it has been found sufficient to merely heat the bronze shell and tin the bearing surface. The shell is bored out to size and after tinning, a sizing reamer is pushed through in order to smooth off the bearing surface, which still retains the tin coating, showing that the tin has amalgamated with the bronze.

This process has given good results, but the 1/32-in. thick coating mentioned before is better to use, since it has longer life. After all, the arrangement of oil grooves and provision for lubrication are very important factors in the life of a bearing, and have considerable influence upon its performance. A high-grade babbitt may not always give satisfactory results if the bearing is incorrectly designed or neglected.

R. PRUGER.
Mechanical Engineer,
Westinghouse Electric & Mfg. Co.,
East Pittsburgh, Pa.

In the Repair Shop

This section is devoted to repair work on electrical and mechanical equipment. Special attention is given to shop or bench tools and short cuts or improved methods of handling work of this character. Contribution are always welcome.

Simple Motor-Generator Set for Testing A. C. Motors

OFTENTIMES in repair shops in which only direct current is available, it is necessary to test small single- and poly-phase motors after rewinding. The following information will be of help in solving the problem which is thus presented.

The first step is to secure a three-phase, 60-cycle, 440-volt, a.c. generator which should be driven by a shunt-wound, d.c. motor. If the largest a.c. motor to be tested is of 1-hp. rating, the motor that drives the generator should be of not less than 3-hp. rating at 1,800 r.p.m. This will give about 1.4 hp. at 750 r.p.m., when testing 25-cycle machines. A 5- or 6-hp. motor would give more satisfactory results, because the set could then be used to test motors larger than 1-hp. rating at higher frequencies. A 1,500-r.p.m. motor, with a suitable resistance in the field circuit to raise the speed up to 1,800 r.p.m., and an ordinary rheostat in series with the armature to reduce the speed below normal, may be used to drive the generator.

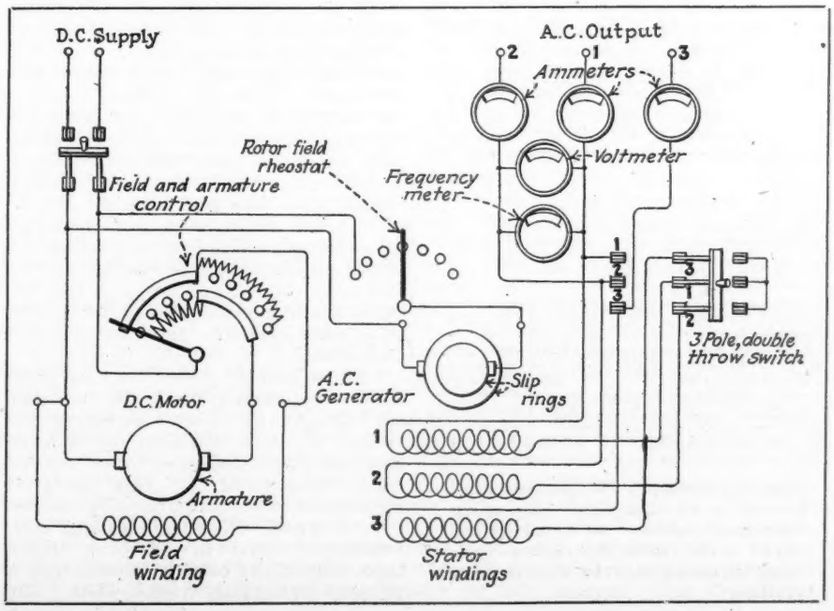
The accompanying diagram shows how armature and field control rheostats can be worked by the same switch arm. A 3- or 5-hp., a.c. generator, would be large enough if the motors to be tested do not exceed 1-hp. rating, however, with larger generators the voltage regulation would be better under different loads. A three-pole, double-throw switch and a rheostat in the rotor field circuit should be used for controlling the voltage of the generator, which should be wound for 440 volts in order to deliver 220 volts at the low speed required for 25 cycles. As shown in the diagram, when the three-pole switch is thrown to the right the stator windings are connected in star, and when thrown to the left, in delta.

The following table shows the voltages that can be obtained for testing, by varying the speed and winding connections of the generator.

Speed	Cycles	Connection	Volts
1,800	60	star	440
1,800	60	delta	256
750	25	star	220
750	25	delta	127

The voltages of 256 and 127 may be reduced to 220 and 110 volts respectively by regulating the field rheostat.

Wiring diagram of motor-generator set for testing small a. c. motors.
The desired testing frequency is readily obtained by means of the armature and field control which controls the speed of the shunt-wound driving motor. The voltage is regulated by the rotor field rheostat, and the three-pole, double-throw switch. When this switch is thrown to the right, the stator windings of the generator are connected in star; when the switch is thrown to the left, the windings are connected in delta.



By adjusting the speed of the driving motor until the frequency meter shows the desired reading all frequencies from 25 to 60 cycles may be obtained. If single-phase current is to be used it may be taken from any two of the three generator leads. A voltmeter is necessary to ascertain the correct voltage and a frequency meter should be used to show the frequency of the set. Three ammeters are shown in the accompanying diagram. These will be of considerable help in locating trouble in a motor under test. One ammeter could be used, but it would have to be switched from one phase to the other. I once had a set like this made from two old 10-hp., d.c. motors and it worked very satisfactorily. A squirrel-cage induction motor will also make a good generator, if another rotor is installed in it.

FRED LARSON.
Duluth, Minn.

Vital Factors in Selection of Ovens for Baking Coils and Armatures

IN A recent issue of INDUSTRIAL ENGINEER I noticed an answer to P. F. W. of Pedro Miguel, Canal Zone. His question was, "What shop equipment will be required here?" I read over this answer very carefully and found that when the author came to the oven recommendations he gave sizes and mentioned that the oven should be built of brick or some other insulating material; also that the oven might be electrically heated if gas was not available, or that it might be fired by oil, or steam-heated.

I take exception to some of the author's statements and for the purpose of clearing up any misunderstandings which might arise I wish to call attention to the following facts.

An oven, to give good satisfaction, should not be constructed of brick, as brick and mortar absorb a great amount of heat, which is usually expensive. From actual tests, a brick oven for even operation must have heating units of 30 per cent greater capacity than an oven of the double-wall type, with only 2 in. of insulation, this being made up of mineral wool, 85 per cent magnesia block or other insulating material of equal value.

It has taken us over twenty years to determine the correct amount of ventilation for various sizes of ovens. Ventilation is one of the most important features of an oven when it comes to baking coils and armatures, for if the ventilation is too great,

waste of heat will be the result and under ordinary circumstances the oven cannot be brought up to temperatures high enough to bake properly. If the ventilation is not thorough enough, the oven will act sluggishly and it will be impossible to bake properly, due to the re-circulation of the fumes which are being carried off by the ventilation. Ventilation must be arranged so as to draw the heated air down through the top of the oven. This is done by having ventilating ducts on the floor of the oven, which brings the heat downwards so as to effect uniform heating in all parts of the oven. There must be some top ventilation, as the bottom ventilation carries off only the heavy gases while the top ventilation will carry off all the light vapors.

Another important point to consider in the ventilation of the oven is the fresh air ducts. Fresh air must be had for baking coils and armatures, due to the fact that varnish will not oxidize without it. This fresh air must be admitted uniformly and in the proper amounts to secure proper oxidation.

The author states that the oven might be electrically heated if gas is not available. If I were to equip a shop similar to the one mentioned I would reverse his statement, for gas, oil, and steam should be used only when electricity is not available. The following are the reasons for this statement: The average period of bake on armatures of large cross-sectional area is from 12 to 16 hr., and the temperature should be maintained within close limits. From our experience it is quite difficult to subject coils and armatures to a uniform temperature with a gas oven.

We would not recommend oil-fired ovens under any circumstances, as we feel that it is folly to have a flame of high temperature and small area in any part of the oven. A flame of this character will promote uneven heating, as the oven will be very hot in some places and cold in others. We frequently have inquiries for oil-burning ovens for coil and armature baking and in every instance we explain to the customer the difficulties with this form of heat.

The steam oven is not very practical, although it is used by large manufacturers who have considerable quantities of superheated steam. This condition is not found in the small coil and armature shop and, therefore, a steam oven cannot be used unless a steam boiler of high pressure is installed. To heat the oven to 200 deg. F. it is necessary to have superheated steam at high pressure. Unfortunately, even large plants who use this system have found it almost impossible to keep their ovens up to the proper temperature. We are now building an oven for one of the largest users of small coils in the world, and we do not guarantee the oven, unless they guarantee the steam pressure which we specify.

In taking up the subject of coil and armature baking it has been the writer's intention to promote a better understanding of oven requirements and it is for this reason that I called attention to the above factors. I feel that the average coil and armature shop does not understand what an oven should be capable of doing in order to turn out the work properly. I wish to see better conditions in this field so that coil and armature shops may turn out better work; that is, properly baked so as to give the best results. I know that if these shops would install the proper baking equipment, a great many large manufacturers would go back to them for repairs, instead of installing their own shops. One large manufacturer recently told me, when I asked him why he had put in his own shop, that there was not one commercial shop in his city equipped to do repair work that would hold up under the severe conditions in his plant.

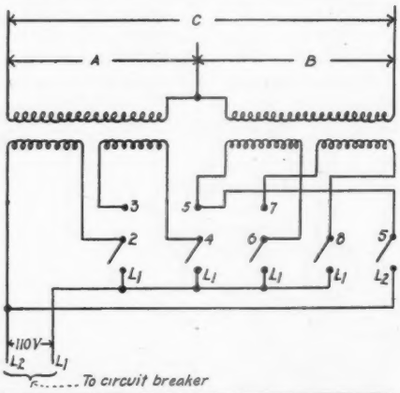
H. L. GRAPP.
Sales Manager,
Despatch Manufacturing Co.,
Minneapolis, Minn.

How to Connect Two Testing Transformers for Various Voltages

IN ALL electrical repair shops it is necessary to have different voltages for testing purposes. On the other hand, it is a difficult job to rewind a transformer in the average shop and to bring out taps for all of the voltages desired.

An easy way of getting around this difficulty is to convert two 2200/220/110-volt transformers of the same size as shown in the diagram. From these the following voltages may be obtained: 4,400, 3,300, 2,200, 1,467, 1,100, 733, and 550. In this range there is a suitable voltage for any ordinary test. The table shows the connections for obtaining any of the above voltages. These connections may be left on the line for all voltages except 4,400, which should be taken off as soon as possible.

Detroit, Mich. C. H. FUNDERBURG.



Close switches so as to connect	Volts delivered at A	B	C
2 to 3, 4 to 5, 6 to 7, L1 to 8	550	550	1100
2 to 3, L1 to 4, 6 to 7, L1 to 8, L2 to 5	1100	1100	2200
2 to 3, 4 to 5, L1 to 6	733	733	1466
2 to 3, L1 to 4 L1 to 6, L2 to 5	1100	2200	3300
L1 to 2, L1 to 6, L2 to 5	2200	2200	4400

The transformers are connected as shown in the diagram. By using the combinations of connections given in the table, the various voltages indicated may be obtained for testing.

Changing One-Coil-per-Slot Windings to Two Coils per Slot

THERE are a large number of induction motors in service in which the stator winding is of the type known as one-coil-per-slot windings. Examples of these are the basket winding used on the old Westinghouse Type CCL and HF stators, the concentric chain, mush-coil winding, and the group, two-layer-end, one-coil-per-slot winding. These windings are hard for the average winder to handle; therefore, it is often desired to change over to the more familiar two-layer, two-coil-per-slot, diamond mush-coil, flat or pulled. This article will discuss the various points of each type of winding and the method of developing the new winding. First, a few general rules and statements will be given after which each type will be considered separately.

The one-coil-per-slot winding always requires one-half as many coils as there are slots; that is, a 72-slot stator would have 36 coils, a 48-slot stator 24 coils, and so on. Coils per group, L, will equal total number of coils, C, divided by number of pairs of poles, P, times number of phases, K, or $L=C \div (P \times K)$. The number of coil groups$=(P \times K)$ or $C \div L$. When changing to a two-layer winding, the number of coils will equal the number of slots; therefore the number of groups=number of poles×number of phases and the coils per group will be the same as for one coil per slot. The coils per group and their arrangement is one of the points to check and the coil grouping tables and diagrams published in previous issues of INDUSTRIAL ENGINEER can be used for this work. The total turns per phase should be kept the same, unless changing the coil pitch requires the addition of turns, as will be explained later. The size of wire should be kept the same, unless the machine is worked hard and it is found that a larger size wire can be used; in this case, put in all the copper that slot and end room permit.

On the majority of one-coil-per-slot, mush windings, the ends of all the coils are taped from slot to slot with one, half-lapped layer of 0.007-in. cotton tape. With the basket winding, the ends of all coils are taped with one layer of half-lapped, 0.01-in., treated cloth tape and one, half-lapped layer of 0.007-in. cotton tape. Here is where considerable time and material can be saved when cutting over to a two-layer, mush-coil winding; for most industrial motor applications, the taping on the coil ends can be omitted and the finished winding given two or more dips in a black, plastic, insulating varnish and baked.

The following gives two standard methods of insulating mush coil ends for voltages up to and including 440 volts. (1) Use 0.023-in., combination slot insulation, fishpaper with treated cloth cemented to it. This has good mechanical and electrical characteristics. Tape all coils ends with one, half-overlapped layer of 0.007-in., cotton tape, reinforcing between phases with a piece of triangular, treated cloth. Dip

and bake the complete winding once in a good baking varnish.

(2) Use 0.023-in. combination slot insulation; do not tape the coil ends but insert a triangular piece of 0.01-in. treated cloth between each coil on both ends. The last coil of each pole-phase group may be taped with one, half-lapped layer of cotton tape and then dipped at least twice in a good, black, plastic varnish, and baked.

Whichever of these methods is best suited to the conditions should be selected. The distribution factor is not changed, as this is based on the number of slots per pole per phase and is the same for the same number of slots, poles and phases. The chord factor is changed only when the coil pitch is varied and in general the chord factor can be increased or decreased 8 per cent without adding or subtracting turns per coil or phase to compensate for the changed pitch.

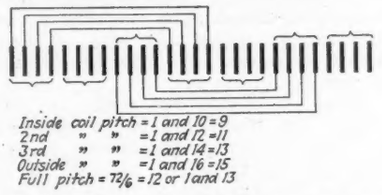
The following values of chord factors are based on per cent of coil pitch; full pitch equals 100 per cent and chord factor equals 1 or unity; 95 per cent pitch equals 0.998; 90 per cent equals 0.98; 85 per cent equals 0.97; 80 per cent equals 0.95; 75 per cent equals 0.93; 70 per cent equals 0.9; 65 per cent equals 0.86; 60 per cent equals 0.81; 55 per cent equals 0.76, and 50 per cent equals 0.7.

The per cent coil pitch of basket windings, two-layer, one-coil-per-slot, and two-layer, two-coil-per-slot windings, can be found as follows. First, find the full pitch, which is equal to total number of slots divided by the number of poles; that is for 72 slots, and four poles full pitch equals $72 \div 4 = 18$ or 1-and-19. Next, divide the coil pitch of the winding, expressed in slots, by the full pitch found. If present pitch is 1-and-16 or 15, per cent pitch equals $15 \div 18 = 0.833$ or 83.3 per cent. These general remarks apply to all types of windings.

Taking up each type of winding, the coil pitch in the basket winding must necessarily always be an odd number, or 5, 7, 9, 11, and so on, or 1-and-6, 1-and-8, 1-and-10, and so on, because one slot must be skipped between each coil as they are placed on the core. Also, the extensions of the coil ends in this type of winding are shorter than with a two-layer coil of the same pitch and turns. The short coil extension is due to the method of shaping the coils down against the iron. Thus it may be necessary in some cases to reduce the coil pitch in order to use a two-layer winding. A saving in slot and end room can be made by using single-cotton and enameled wire to replace the double-cotton-covered wire used in all of these windings.

Assume that we have a 72-slot motor, with 36-coil, basket winding, which it is desired to change to a two-layer winding. The basket winding requires only 36 coils, which means less time to make the coils and put them in the core. However each coil has to be taped on the ends with a layer of treated cloth and cotton tape and also requires shaping. On the other hand, with a two-layer winding we would have to make up 72 coils, but as the turns per coil are one-half the number in the basket winding, it would not require very much more time. Again, if it were decided to tape the ends, the taping time on the two-layer winding would be less, since there would be two layers of tape on each basket coil, which is equivalent to taking 72 coil ends. The taping of the ends for the two-layer winding would take a little less time and would also require less shaping. Unless a winder who is experienced on basket-type windings is available, the two-layer winding would make the best job.

The motor under consideration has a three-phase, four-pole winding, six groups, six coils per group, pitch 1-and-16 or 83.3 per cent, each coil having 14 turns of three No. 14 d.c.c. wires. The



This shows the procedure involved in changing a 72-slot, 6-pole, 36-coil, concentric chain winding from a one-coil-per-slot to a two-coil-per-slot winding.

two-layer winding data would be, as previously explained, 3 (phases) $\times$ 4 (poles) $=12$ groups, six coils per group, 72 coils each having seven turns of three No. 14 s.c.e. wire, pitch 1-and-15, or one slot less, giving a 5.5 per cent decrease, which changes the pitch to 77.8 per cent. The reason for dropping one slot was to reduce the coil end extension and shorten the coil, reducing the weight of copper.

Assume that the end room available in the above case would permit a coil pitch of only 1-and-12, or 61 per cent. In this case, it would be necessary to add turns to each coil as follows: $(83 \times 7) \div 61 = 9.5$ or 9 turns per coil. According to this formula, new turns per coil equal old per cent coil pitch times the turns per coil for the two-layer old coil and divided by the new per cent coil-pitch. The per cent of coil pitch should be expressed as a whole number: that is, 83 not 0.83. Do not drop below 50 per cent pitch and when possible keep around 80 per cent.

Considering the next type of winding, it is one in which the coils are put on in groups. Although there is only one coil per slot, the ends are arranged in two layers; in fact, the coils resemble the standard two-layer, mush pulled coil. The coil pitch in this type of winding depends on the number of coils per group and the pitch will be even when the coils per group is an even number or odd when the coils per group is an odd number. The reason for this is that the coils are put on in groups; that is, with three coils per group, we first put in three coils in adjacent slots, then skip three slots and put in three more. The slots left empty are later used for the top halves of the coils. The only advantage to be had in changing this type of winding to a two-coil-per-slot winding is a slight decrease in end room and a lighter coil. If the ends of the two-coil-per-slot windings can be left untaped, then this latter winding would save time and material. The ends of the group winding are insulated in the same manner as the basket winding; with both these windings the extra insulation on the coil ends is necessary, due to the method of shaping and arranging the end winding. The same method of changing the basket type can be applied to the group windings.

Another type is the concentric chain winding. There is a decided advantage in changing this type to the two-coil-per-slot, two-layer winding for single rewind jobs, as the chain winding requires a number of different sizes of molds and some shaping. When there are a number of motors of the same kind to be rewound, the chain winding has the advantage as a gang mold can be made and a complete pole-phase group wound without cutting the wire, thus reducing the connecting time. The coil pitch of this type depends on the number of slots per pole per phase, as the pitch of the inside coil is selected so as to span a number of slots equal to the slots per pole per phase for two-phase motors. For three-phase motors the slots spanned will be the number of slots per pole per phase times two.

From this it is seen that the coil pitch will be both under and over 100 per cent. It should be understood that over-pitch has the same effect as under-pitch; that is, 120 per cent pitch is equivalent to 80 per cent pitch electrically, but the over-pitch coil requires more copper. These points can best be explained by an example: Assume a 72-slot, six-pole, three-phase stator with a concentric chain winding as shown in the accompanying diagram. The winding has 36 coils, nine groups, four coils per group and the end winding is arranged in two ranges, so that eight different sizes of coils are required.

According to the rule previously given, the slots spanned and left unused by the inside coils for three-phase, should be twice the number of slots per pole per phase. We have 72 slots or $72 \div 6 = 12$ slots per pole; $12 \div 3 = 4$ slots per pole per phase, and the pitch of the inside coil is $2 \times 4 = 8$, or 1-and-9. As indicated in the diagram the different coil pitches are as follows: full pitch is $72 \div 6 = 12$, or 1-and-13; the inside coil pitch is 9 or three slots under full pitch; the second coil pitch is 11, or one slot under full pitch; the third coil pitch is 13, or one slot over, which is equivalent to one slot under pitch, or eleven. Outside coil pitch is 15, or three slots over, this being the same as three slots under pitch, or 9, and the average coil pitch equals $9+11+11+9 \div 4 = 10$. In order to obtain the same average chord factor with a two-layer winding, the coil pitch should be 10, or 1-and-11. If the coil-end extension with the 1-and-11 pitch is too great, the pitch can be decreased as explained by varying the number of turns per coil.

The foregoing rules and details explain the points that require checking and consideration when changing over any of the types of windings mentioned to a two-layer, diamond-shape, coil winding. The best type of coil to use for the two-layer winding is the mush pulled coil, as this type of coil requires less shaping when winding the stator.

Wilkinsburg, Pa. A. C. ROE.

New Equipment

for plant operation and maintenance

Industrial plant executives concerned with the selection and operation of mechanical and electrical equipment will be interested in these new devices which are designed to improve plant operation or reduce operating and maintenance costs.

Plate-Type Field Rheostats

A NEW line of field rheostats of the round-plate type in which the cast-iron plate previously used has been superseded by pressed steel, has been placed on the market by the Ward Leonard Electric Co., Mount Vernon, N. Y. This type of plate can be furnished completely inclosed, including the terminals. As in the case of the cast-iron, plate-type rheostat, the resistive conductor, its contacts and the joints between the contacts and the resistive conductor, are completely embedded in vitreous enamel.

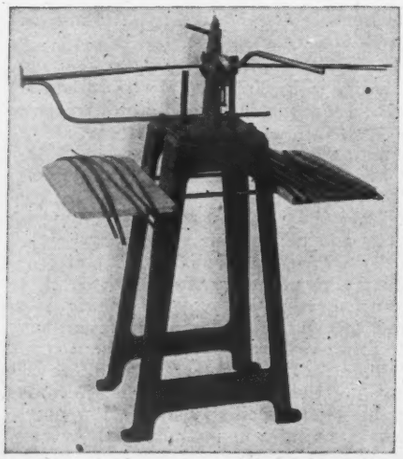
Portable Rail Bond Tester

THE new Type BBT Bond Tester and the Type B Contact Bar are announced by Roller-Smith Co., 233 Broadway, New York City. This new, portable, direct-reading bond tester is designed for applications where the current in the rail is feeble or at the ends of trolley lines where no cars are running beyond the points where tests are being made.

It is stated that this bond tester has over five times the sensitivity of any bond tester heretofore made. It can be successfully used with the current from a single No. 6 dry cell. The special contact bar carries a bracket for this dry cell, with the necessary battery switch and contacts.

Strap Copper Bar Bender

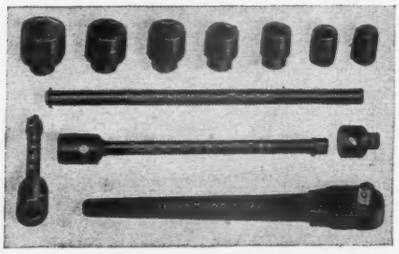
THE machine in the accompanying illustration is announced by the Armature Coil Equipment Co., 2415 Forrestdale Ave., Cleveland, Ohio, for bending insulated or bare strap copper bar over its edge. The manufacturer states that in bending cotton-insulated copper bar it will not destroy one thread at the bend, and bends bars with any other insulation equally well. This machine can be used to bend one or more loops at a time and is provided with a stop limit to insure uniformity of shape. The machine can be adjusted to make any size of loop within its range. The loops are formed by two bending arms.



These machines are made in two sizes. The small size has a capacity of stock for one or more loops of any thickness up to ½ in. and ¾ in. in width. The capacity of the larger machine is bar stock 1 in. thick, up to 1¼ in. in width. Loops on the small machine may be bent over a ½-in. radius; the larger machine bends loops over a 5-in. radius.

Quick-Detachable Wrench Set

THE No. 12 quick-detachable industrial wrench set, as shown in the accompanying illustration, has been placed on the market by the Blackhawk Mfg. Co., Milwaukee, Wis. This is an extra-heavy-duty set, designed for service in shops and industrial plants.



The set includes a 20-in. ratchet wrench handle, one sliding bar 1 in. in diam. and 24 in. long, one short extension ⅞ in. in diam. and 9 in. long, one 18-in. extension, one offset adapter, and seven hexagon sockets for bolts; ranging from 1¼ to 2⅜ in. in size. The set weighs 46 lb. and is contained in a wooden box.

Changes in Lowering Switch

A NUMBER of improvements in the Thompson safety lowering switch or disconnecting hanger have been announced by The Thompson Electric Co., 1438 W. 9th St., Cleveland, Ohio. To make provision for easier inspection and cleaning of the parts, when it is necessary, the design of the new underslung model has been changed so that all of the moving parts except the wheel come down to the ground when the lamp is lowered. The hanger should be operated frequently enough to prevent the parts from becoming sticky from dirt or corrosion. The latchdog is so designed that it can be easily and quickly removed for cleaning. Another improvement provides for enclosing the line wires as they enter the upper member of the hanger. Still another change provides for a swiveling arrangement for dead-ending the chain in the lower member, thus enabling the lamp to rotate freely so as to bring the contacts into proper alignment for seating into each other. Provision is also made for enclosing the chain in conduit.

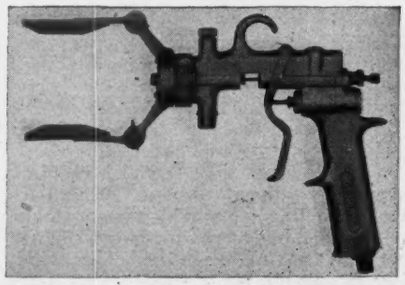
Small Reducing Gear

TYPE 2, small reducing gear manufactured by Winfield H. Smith, Springville, Erie Co., N. Y., has been improved, as have the Nos. 4A, 5 and 8. The Type 2 reducer, shown in the accompanying illustration, retains the same center distances, shaft sizes and shaft extensions as the former model. This unit is equipped with bronze-bushed bearings for the high-speed shaft. The gear case provides for a greater oil capacity and is more rigid in construction than the former model. A screw plug at the top of the case provides for filling the chamber. Gear reduction of 48:1 or 30:1 can be had. The unit is regularly equipped with a 4-in. grooved pulley on the drive shaft and four-step grooved pulleys of 1, 1½, 2 and 2½ in. diameter on the driven shaft.

Spraco Lobster Claw Attachment

SPRAY painting has its application widened by means of the Lobster Claw Attachment shown in the accompanying illustration, which enables the spray operator, according to the manufacturer, to include every line within the architectural and industrial finishing fields, as this little auxiliary makes possible the cutting-in of trim on windows, doors, moldings, wall fixtures, and also the cutting between ceilings and walls, baseboards and floors, and other applications. This device is announced by the Spray Painting and Finishing Co., 60 High St., Boston.

Portable paint spraying equipment is of particular interest to the plant engineer as it supplies a speedy, easy, and economical method of painting buildings and other stationary objects.



A coverage of 4,000 to 5,000 sq. ft. can be obtained in an 8-hr. day, it is stated, while as much as 10,000 sq. ft. is often painted on large, free surfaces as compared with a range of 700 to 1,100 sq. ft. by the hand method. As a matter of average experience, spray painting uses approximately the same amount of paint but saves from 60 to 80 per cent of the labor cost.

Direct-Current Motor

A NEW line of 40-deg.-rating d.-c. motors, Type "NA," has been developed by The Louis Allis Co., Milwaukee, Wis. The new line of motors is interchangeable, rating for rating, in all essential dimensions with the Louis Allis polyphase motors. It is said that in this new line improved design and ventilation insure uniform cooling throughout the windings. The bearing chamber is designed to hold an extra quantity of oil. Bearing inspection is made through a removable cover, which, while permitting easy inspection, gives in effect a dust-tight bearing chamber. Elimination of oil trouble is claimed by virtue of a new design incorporated in the bearing.

Smoke Detector and Fire Extinguisher

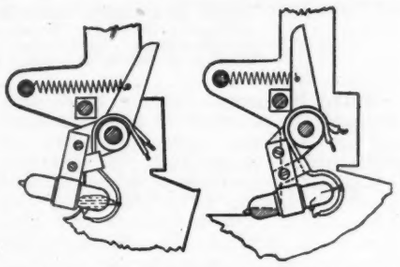
EQUIPMENT for indicating or detecting smoke and provision for the extinguishing of fires in enclosed or semi-enclosed electrical or other equipment is announced by Walter Kidde & Co., Inc., 140 Cedar St., New York City. The Rich system of smoke detection is employed. This makes use of a beam of light from a lamp, and a mirror. As long as the air in a machine or compartment remains clear the beam of light from the lamp remains invisible to the operator looking into the mirror. However, as soon as the air contains smoke particles a strong beam of light is observed. When smoke is thus indicated to the operator provision is made whereby he can, by the Lux system of fire extinguishing, release pure, dry carbon dioxide under pressure from steel cylinders, to smother the fire. It is stated that a single battery of cylinders can be connected up to protect any number of machines and compartments. The control for the release of the gas may be electrical or manual or both and be placed where desired.

This combination system is used to indicate over-heating sufficient to cause smoke, particularly in enclosed machines with ventilating systems, before a fire occurs. It is claimed that the Lux system of extinguishing fires may be used in transformer and oil switch rooms and in other similar places, as electrical fires may be extinguished in "live" equipment without damage and without removing the power from the circuit.

This system of detecting and extinguishing fires may also be used, it is stated, for protecting paint rooms, paint spray booths or other places where highly flammable oils or liquids are used. It may also be used for protecting wood pulverizers and other enclosed machinery of this general type.

Mercury Contact Switch on Pyrometer Recorder

A MERCURY contact switch which has been developed by Charles Engelhard, 33 Church St., New York City, to decrease electrical contact troubles in connection with pyrometer recorders is shown in the accompanying sketch.



This consists of a small glass tube containing mercury, a minute quantity of oil and an inert gas. Platinum electrodes pass through and are sealed in the glass tube. In the position shown at the left, the mercury makes contact with both of the electrodes and thus completes the circuit. Where the tube is tilted slightly to the position shown at the right, the mercury flows away from the terminals to the other end of the tube and breaks the circuit. A separate mercury switch is used for each pyrometer circuit and the required number of contacts are mounted side by side within the recorder case. The resistance, it is stated, is from 0.003 to 0.004 ohms. These mercury switches are said to be fume- and dust-proof and are designed for use in connection with electric resistance thermometers and thermo-couples, where extremely high precision is required.

Manual D. C. Controller

ANNOUNCEMENT is made by The Clark Controller Company, Cleveland, Ohio, of a new, improved, face-plate-type, manual controller which, it is said, has been built for heavy-duty service, and is suitable for overhead traveling cranes, charging machines, mill tables, or any application where reversing of the motor is necessary and where hand operation is suitable. The frame of the controller, including the top and the base, is of heavy, pressed-steel plate.

The shaft which carried the contact arm rotates in a radial-thrust ball bearing near one end of the shaft and a graphite bronze bushing near the other end of the shaft. A magnetic blowout feature is provided in both sizes of controllers, which cover a range from 1 to 50 hp. at 230 volts and proportional ranges in other voltages.

Resistors of special alloy steel, which has been drawn or rolled—not cast—are used. The accompanying illustrations show (left) the No. 2 Clark manual controller, Type F, Form R; a disassembled view (center) shows the Type E M B resistor and the ease of removing or replacing the resistor filling. The view at the right shows the back of this controller with a Monitor Edgewound resistor.

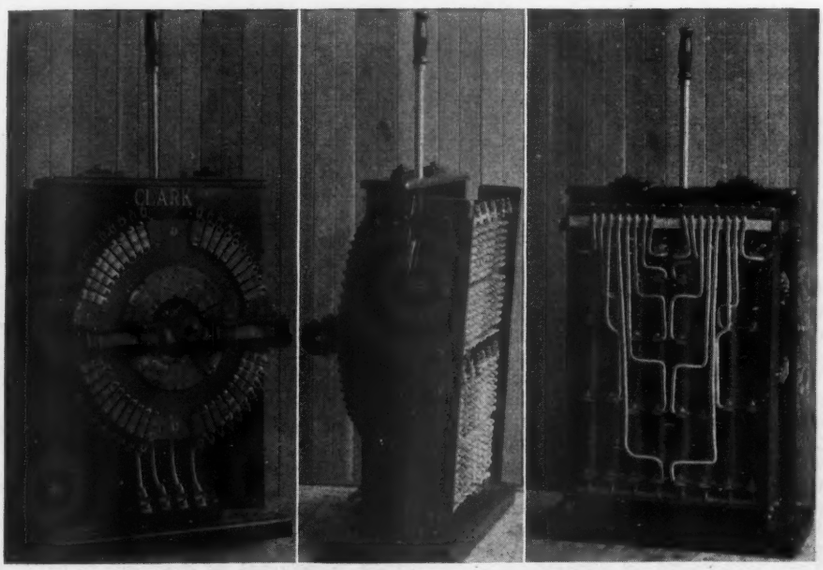
Controllers of the same general type for a.c., three-phase, slip-ring motors are also manufactured.

Panelboard for Industrial Use

NEW lines of industrial panelboards for the control of lighting systems in offices and factories have recently been announced by the Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa. These panelboards are made in sizes supplying from 4 to 32 circuits and in capacities ranging from 30 to 100 amp.

The new panelboards are constructed with two doors, one within the other. The smaller door, giving access to the switch compartment, has a snap catch and may be opened by anyone. The larger door, opening into the fuses, is equipped with a Yale lock so that only authorized persons may open it.

Both types of panelboards are built up in unit construction, with eight single-pole or double-pole switches. When single-pole switches are used the switch unit consists of two single-pole switches built on a composition base. With double-pole switches, a unit consists of one double-pole switch on a



base of the same material. These units may be easily removed from the front of the panelboard, which makes any necessary inspection and replacement easy, according to the statement of the manufacturer.

The cabinet fronts of these panelboards are equipped with the Westinghouse standard trim clamp for mounting the trim on the box. This clamp permits easy adjustment of the panelboard trim when the box has been set up out of plumb. The trim clamp allows adjustments up to ¾ in. in depth and laterally.

Oil Burner and Preheater

IN WELDING castings, preheating is oftentimes necessary to neutralize expansion and contraction strains, or to effect economy of gases. Without preheating, complicated castings are liable to develop new breaks at points remote from the weld after the weld itself has been successfully completed. The Milburn oil burner and preheater, which is primarily designed for this work is of the atomizing type and, it is stated, utilizes the cheapest grades of crude, fuel, kerosene oil or distillate, and compressed air under pressures varying from 50 to 100 lb.

The air-supply line furnishes a direct flow to the burner, and also maintains a similar pressure in the oil storage tank. Immediately upon opening the valves, the gas at the burner can be ignited.

Improved Resistance Starter

PRIMARY resistance starters, manufactured by the General Electric Co., Schenectady, N. Y., for squirrel-cage, induction motors, bearing the designation CR-7056-D-1, have been superseded by two improved types, the CR-7056-D-3, which is produced in sizes for use on motors up to 25 hp., and the CR-7056-D-4 for motors of 25 to 50 hp. The former has arc barriers and the latter is equipped with magnetic blowouts and arc chutes which permit it to handle safely the larger motor currents.

Both starters have an improved magnetic time interlock. The operating spring now works by compression instead of tension. The interlock can thus be adjusted more easily. The starting resistors have been redesigned to provide a greater capacity and to conform to Classification No. 16 of the Electric Power Club, which provides for 200 per cent full-load current or more on the first point for 15 sec. out of every four minutes.

The case for the D-3 starters opens from the top and is ventilated. It has two 1¼-in. knockouts both in the top and in the bottom, providing ample space for the power and the control wires.

The starter cover may be padlocked shut if desired. The D-4 case is larger than that of the D-3 to accommodate a larger resistor. This case opens on the side and can also be locked. It is provided with four 2-in. knockouts. Both models weigh 122 lb. and are arranged for wall mounting.

Trade Literature
you should know about

Copies of literature which is described on this page can be obtained by writing to the manufacturer whose name and address are mentioned. It is always advisable to state the name and number of bulletin or catalog desired, as given in these columns.

Speed Reducers—Catalog 14 devotes 68 pages to descriptions and discussion of the various types and sizes of Philadelphia worm, spur and herringbone gear speed-reducer units. Dimensions and ratings of the different types are included.—Philadelphia Gear Works, Richmond & Tioga Sts., Philadelphia.

Oil Purifying—Bulletin 107 discusses the De Laval method of purifying transformer oil and switch oil by the application of centrifugal force. The operation of the centrifugal separator is illustrated by diagrams and a large number of installations are shown.—The De Laval Separator Co., 165 Broadway, New York City.

Chucks—Catalog 520 describes and illustrates various types and sizes of Westcott drill and lathe chucks.—Westcott Chuck Co., Oneida, N. Y.

Formica—A booklet entitled, "What Formica Is," describes how Formica is made, the different grades, and some of the numerous applications.—The Formica Insulation Co., 4633 Spring Grove Ave., Cincinnati, Ohio.

Portable Electric Saw—A circular describes and illustrates a number of uses of The Crowe Safety Saw, which is made in three sizes, to take 6-in., 8-in., and 12-in. blades.—The Crowe Mfg. Corp., 133 E. Third St., Cincinnati, Ohio.

Variable Speed Transmission—Catalog 20 describes the Lewellen variable speed transmissions and various types of manual and automatic controlling devices. This transmission unit permits operating a machine at a variable speed from a driving unit of fixed speed.—Lewellen Manufacturing Co., Columbus, Ind.

Flexible Couplings—A circular discusses the question of fatigue in couplings, with particular attention to the Fast flexible couplings.—The Bartlett-Hayward Co., Scott & McHenry Sts., Baltimore, Md.

Non-Metallic Gears — Publication C-1579-D discusses the computation of horsepower ratings of Micarta gears, with examples, and gives tables of the preferred pitch, the values of the constants used, gear data, and the horsepower ratings at various pitches. The qualities and advantages claimed for Micarta as a material for gears and pinions are well covered.—Westinghouse Electric & Manufacturing Co., Pittsburgh, Pa.

Brazing Outfit—A circular describes the Smith's No. 8 brazing outfit and the various tips and attachments.—Smith's Inventions, Inc., 2633 Fourth St., S. E., Minneapolis, Minn.

Speed Indicators—A circular shows the construction and use of a Hasler speed indicator for giving direct measurements of speeds either in r.p.m. or f.p.m.—Hasler-Tel Co., 461 Eighth Ave., New York City.

Short-Center Drive—Bulletin 1228 describes the Allis Texrope short-center drive which consists of sheaves on the driving and driven pulleys connected by small V-belts.—Allis-Chalmers Mfg. Co., Milwaukee, Wis.

Ball Bearings—Catalog 25 covers general industrial application of Fafnir ball bearings and gives particular attention to their use in power transmission equipment. Catalog 26 contains, in addition to the general industrial applications, a large number of textile applications.—The Fafnir Bearing Co., New Britain, Conn.

Dead Ending Clamp—A circular describes the Screw Jack dead ending clamp for stranded cable, which is made in sizes suitable for standard cable from 4/O to 2,000,000 circ. mil, inclusive.—The Clark Controller Co., 1146 152nd St., Cleveland, Ohio.

Roller Bearings—Bulletin 1559 gives dimensions and load data on Hyatt roller bearings for industrial equipment and methods and data, including a table of factors for use under various service conditions, for determining the size of bearings for different loads.—Hyatt Roller Bearing Co., Harrison, N. J.

Ball-Bearing Tool Grinder—A circular describes the Bodine double-head, ball-bearing tool grinder operating at 3,400 r.p.m. These are made in two sizes, with ¼- and ½-hp. a.c. or d.c. motors.—The Bodine Electric Co., 2256 West Ohio St., Chicago, Ill.

Roller Chains and Sprockets—Catalog 57, 84 pages, covers the dimensions, rating and other data on Diamond chains, with a chart for their selection, and a discussion of their lubrication, installation and care.—Diamond Chain & Mfg. Co., Indianapolis, Ind.

Crane, Hoist and Mill Controllers—Bulletin 330 illustrates the construction, operation and characteristics of the Type F-2250 Allen-Bradley crane, hoist and mill controller.—Allen-Bradley Co., Milwaukee, Wis.

Pneumatic Tools—A 42-page, pocket size catalog describes the line of Thor piston and turbine pneumatic drills, hammers, foundry tools, and motor hoists.—Independent Pneumatic Tool Co., 600 W. Jackson Boulevard, Chicago.

Ball and Roller Bearing Motors—Bulletin 4000 illustrates and describes the bearing construction of d.c. and a.c. Reliance motors fitted with ball and roller bearings, and explains the various advantages claimed for them.—Reliance Electric & Engineering Co., 1051 Ivanhoe Road, Cleveland, Ohio.

Electric Melting Pot—A circular describes the Trent electric melting pot for continuous service. These pots are made in capacities of 10 to 1,500 lb. of lead, and are used for melting babbitt, solder, lead, tin, and other metals.—Harold E. Trent, 259-61 N. Lawrence St., Philadelphia, Pa.